VERBAL DISCRIMINATION LEARNING IN A RANDOM MIXTURE OF TWO-, THREE-, AND FOUR-WORD ITEMS WITH TWO STIMULUS PRESENTATION RATES

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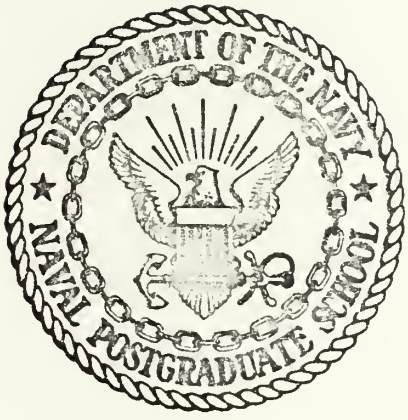

THESIS

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by

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by

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ABSTRACT

The purpose of the experiment was to determine whether a constant information processing rate would occur when subjects in verbal discrimination (VD) learning were presented a mixture of items of different lengths. Forty-two Naval Postgraduate School students served in a VD experiment with a random mixture of 2-, 3-, and 4-word items at presentation rates of $\frac{1}{2}$ or $\frac{1}{4}$ bits of information per second. Half the items had similar and half, dissimilar words. The VD list had 6 each, of 2-, 3-, and 4-word items resulting in 6 bits of information for the 2-word items, 9.51 bits for the 3-word items, and 12 bits for the 4-word items for an overall presentation load of 27.51 bits of information. The information content of 2- and 3-word items was normalized to agree with the 12-bit base of 4-word items for analysis. The similarity variable was disregarded, since it was not significant as a main effect. The results showed that, at each presentation rate, 2-, 3-, and 4-word items were learned at the same information processing rate. Moreover, the interaction between presentation rate and blocks of trials showed an expected multiplicative function such that the performance of one group could be predicted with 93.5 percent accuracy.

TABLE OF CONTENTS

LIST OF TABLES

TABLE

LIST OF FIGURES

FIG.

I. INTRODUCTION

Verbal learning is a form of learning in which all persons engage. William N. Runquist (1966, p.48) in his book on verbal behavior stated:

> The study of verbal behavior has no fixed boundaries. Any experiment in which a verbal response is used to indicate some state of the subject, or a verbal stimulus or cue provides the occasion for some other kind of responses, could be construed as a study of verbal behavior. If, in addition, we include studies in which the experimenter's or the subject's overt verbalizations influence the subject's behavior, the study of verbal behavior encompasses virtually all studies performed on the human organism older than two years.

It was with the above quote in mind that this thesis investigated verbal discrimination (VD) as a method of presenting verbal material for learning.

The characteristics of VD learning that make it possible for its quantification using information theory are its presentation of words in discrete categories as stimuli for learning along with corresponding, discrete, response categories. The information measure provides an absolute measure of learning regardless of the number of alternatives in a verbal discrimination item. That is, when the initial probability of choice for each word in a verbal discrimination item can be estimated, the transfer of information contained within a list of items may then be measured by the distribution of responses among choices over repeated trials. Thus, learning can be analyzed as the reduction of

uncertainty in subjects' responses from the uncertainty initially present in the item. When each item is developed with the criterion of making each word of an item equally probable of being chosen, the information content of the item is simply defined as follows:

$$I = LOG_2\ N$$

where I = Information content

N = The number of words comprising the item

Hence, a two-word item has one bit of information; a three-word item, 1.585 bits; and a four-word item, two bits of information.

In the general case the information content of a VD list would be:

$$I = -\sum_{k=1}^{m}\left[\sum_{i=1}^{n}(P_i\ LOG_2\ P_i)\right]_k$$

where I = Information content

k = The k^{th} item within the list

P_i = The probability of occurrence of the i^{th} word within the k^{th} item

m = The number of items in the list

n = The number of words contained in the k^{th} item

i = The i^{th} word within the k^{th} item

The total amount of information contained in a given list of items is merely the sum of the information contained in each item of the list.

Gray (1971) investigated VD learning as information processing by considering two-, three-, and four-word items

with two presentation rates per item of 1.5 or 3.0 seconds. In addition to finding list length, trials, similarity, and several interaction effects to be significant, Gray established that the amount learned was clearly dependent on the rate of presentation and, within each rate of presentation, the number of words in each item. The rate of learning was shown to be approximately twice as great for the slower presentation rate and proportional to the difference in presentation rates.

The controversy, however, is in Gray's use of two presentation times regardless of the information content of the stimulus. Baltutis (1972) pointed out that, when the information load for each list is approximately the same and the information presentation rate is constant (regardless of the number of words in an item), there should be no difference in the information processing rates; difference in performance should be proportional to the differences in presentation rates.

Baltutis extended Gray's experiment by analyzing the learning of two-, three-, and four-word items utilizing two information (stimulus) presentation rates. Rates were held constant over the word items of different lengths by appropriate adjustments in the presentation intervals. The results of Baltutis' experiment, when analyzed with respect to the information processing measure, indicated that the effects for rate, trials, and rate x item length interactions were significant at the $\alpha = 0.01$ level of significance. The

results indicated that the information processing rate was the same, regardless of the number of words per item, as long as the information presentation rate was the same.

The problem inherent in studies conducted by both Gray and Baltutis is the use of independent groups of subjects for each treatment condition. The problem was further complicated by the generalization of the results to individual VD learning.

A natural extension would be to determine if the results obtained in the study conducted by Baltutis (1972) are still valid if individual subjects are given a random mixture of two-, three-, and four-word items with appropriate adjustments in the presentation interval to maintain a constant rate of information presentation.

II. METHOD

A. WORD LISTS

A word list (Table 1) consisting of 18 word items (six two-word items, six three-word items and six four-word items), was constructed. The two-word items contained 6 bits of information; the three-word items, 9.51 bits of information; and the four-word items, 12 bits of information for a total of 27.51 bits for the entire list.

To insure the equal "a priori" probability of selection on the first trial and to reduce the rate of learning bias (Sidowski, 1966), three criteria were used in determining the words in each list. First, these words were selected from categories having at least a 0.92 correlation over test subjects in the category norms for verbal items compiled by Battig and Montague (1969). Secondly, a similarity variable was established by selecting the words of an item from a single category. Half of the items in each list was composed in this manner; the remaining items contained dissimilar groupings. Finally, the frequency of occurrence of each word in written material was examined using the Thorndike and Lorge (1944) general count. In this respect, all words were required to be members of the AA[1] frequency group.

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[1] AA denotes that in the Record of the Frequency of Occurrence the particular word occurs 100 times or over per million.

Table 1

WORD LIST

Two Word Items

NOSE	NECK	MILK	BOOK*
WALL	DOOR	LEGS	ROSE*
GAME	BALL	HEART	SALT*

Three Word Items

DOG	BEAR	HORSE	IRON	BED	WHITE*
RAIN	SNOW	STORM	BROWN	WOOD	CHURCH*
CAR	TRAIN	BOAT	GOLD	CHAIR	COAL*

Four Word Items

COAT	DRESS	SHOES	HAT	MILE	BLUE	ROOF	HILL*
WEEK	YEAR	HOUR	DAY	RED	INCH	ROCK	YARD*
HAND	FOOT	ARMS	HEAD	ROOM	CLUB	GREEN	HAIR*

* Denotes dissimilar word groups.

- Underlined word in each item was used as the correct response for the experiment.

The correct word within any item was designated by random selection and remained correct throughout the experiment. In addition, the items were randomly arranged into three sequences and three subsequences within each sequence as shown in Tables 2, 3, and 4. A Cox and Stuart test for trend (Conover, 1971, p. 130-132) confirmed the randomness of the arrangement of the items within the three sequences A, B, and C at the $\alpha = .10$ level. Finally, a Cox and Stuart test for trend confirmed the randomness of words within the items.

Table 2

SEQUENCE A

Subsequence A-1				Subsequence A-2				Subsequence A-3			
NOSE	NECK			MILE	BLUE	ROOF	HILL*	BED	IRON	WHITE*	
ROSE	LEGS*			MILK	BOOK*			SNOW	STORM	RAIN	
ARMS	HAND	HEAD	FOOT	WALL	DOOR			ROCK	INCH	RED	YARD*
GOLD	CHAIR	COAL*		DOG	BEAR	HORSE		NECK	NOSE		
COAT	SHOES	HAT	DRESS	BROWN	WOOD	CHURCH*		TRAIN	CAR	BOAT	
SALT	HEART*			WEEK	YEAR	HOUR	DAY	WOOD	BROWN	CHURCH*	
CAR	TRAIN	BOAT		RAIN	SNOW	STORM		BOOK	MILK*		
GREEN	ROOM	HAIR	CLUB*	RED	INCH	ROCK	YARD*	SHOES	DRESS	COAT	HAT
BALL	GAME			IRON	BED	WHITE*		BEAR	HORSE	DOG	
IRON	BED	WHITE*		GAME	BALL			CLUB	ROOM	HAIR	GREEN*
RED	INCH	YARD	ROCK*	CLUB	ROOM	GREEN	HAIR*	HEART	SALT*		
STORM	SNOW	RAIN		CAR	TRAIN	BOAT		DOOR	WALL		
HOUR	WEEK	DAY	YEAR	HEART	SALT*			COAL	GOLD	CHAIR*	
WOOD	BROWN	CHURCH*		COAT	DRESS	SHOES	HAT	HEAD	ARMS	HAND	FOOT
DOG	BEAR	HORSE		GOLD	CHAIR	COAL*		GAME	BALL		
DOOR	WALL			HAND	FOOT	ARMS	HEAD	HILL	BLUE	MILE	ROOF*
BOOK	MILK*			LEGS	ROSE*			ROSE	LEGS*		
ROOF	MILE	HILL	BLUE*	NOSE	NECK			YEAR	WEEK	DAY	HOUR

Table 3

SEQUENCE B

Subsequence B-1				Subsequence B-2				Subsequence B-3			
NOSE	NECK			ROOF	HILL	MILE	BLUE*	WHITE	IRON	BED*	
LEGS	ROSE*			MILK	BOOK*			STORM	RAIN	SNOW	
HAND	FOOT	ARMS	HEAD	DOOR	WALL			YARD	ROCK	INCH	RED*
CHAIR	GOLD	COAL*		HORSE	DOG	BEAR		NECK	NOSE		
COAT	DRESS	SHOES	HAT	CHURCH	BROWN	WOOD*		BOAT	CAR	TRAIN	
HEART	SALT*			HOUR	DAY	YEAR	WEEK	CHURCH	WOOD	BROWN*	
BOAT	CAR	TRAIN		SNOW	STORM	RAIN		MILK	BOOK*		
ROOM	CLUB	GREEN	HAIR*	ROCK	RED	INCH	YARD*	HAT	SHOES	DRESS	COAT
GAME	BALL			WHITE	BED	IRON*		HORSE	DOG	BEAR	
WHITE	IRON	BED*		BALL	GAME			HAIR	GREEN	CLUB	ROOM*
INCH	RED	ROCK	YARD*	GREEN	HAIR	ROOM	CLUB*	SALT	HEART*		
RAIN	SNOW	STORM		TRAIN	BOAT	CAR		WALL	DOOR		
WEEK	YEAR	HOUR	DAY	HEART	SALT*			CHAIR	COAL	GOLD*	
BROWN	WOOD	CHURCH*		HAT	DRESS	SHOES	COAT	ARMS	HEAD	HAND	FOOT
BEAR	DOG	HORSE		COAL	GOLD	CHAIR*		BALL	GAME		
WALL	DOOR			FOOT	HAND	HEAD	ARMS	BLUE	MILE	HILL	ROOF*
MILK	BOOK*			ROSE	LEGS*			LEGS	ROSE*		
MILE	BLUE	ROOF	HILL*	NECK	NOSE			HOUR	DAY	YEAR	WEEK

Table 4

SEQUENCE C

Subsequence C-1				Subsequence C-2				Subsequence C-3			
NECK	NOSE			BLUE	ROOF	HILL	MILE*	IRON	BED	WHITE*	
ROSE	LEGS*			BOOK	MILK*			RAIN	SNOW	STORM	
FOOT	HAND	HEAD	ARMS	WALL	DOOR			RED	INCH	ROCK	YARD*
CHAIR	COAL	GOLD*		BEAR	DOG	HORSE		NOSE	NECK		
HAT	DRESS	SHOES	COAT	WOOD	CHURCH	BROWN*		CAR	TRAIN	BOAT	
HEART	SALT*			YEAR	WEEK	DAY	HOUR	BROWN	WOOD	CHURCH*	
TRAIN	BOAT	CAR		STORM	RAIN	SNOW		MILK	BOOK*		
HAIR	ROOM	CLUB	GREEN*	INCH	YARD	ROCK	RED*	COAT	DRESS	SHOES	HAT
GAME	BALL			BED	IRON	WHITE*		DOG	BEAR	HORSE	
BED	WHITE	IRON*		GAME	BALL			ROOM	CLUB	GREEN	HAIR*
ROCK	INCH	YARD	RED*	ROOM	CLUB	HAIR	GREEN*	SALT	HEART*		
SNOW	RAIN	STORM		BOAT	CAR	TRAIN		WALL	DOOR		
YEAR	HOUR	WEEK	DAY	SALT	HEART*			GOLD	CHAIR	COAL*	
CHURCH	WOOD	BROWN*		SHOES	DRESS	HAT	COAT	HAND	FOOT	ARMS	HEAD
HORSE	DOG	BEAR		CHAIR	COAL	GOLD*		GAME	BALL		
WALL	DOOR			HEAD	ARMS	FOOT	HAND	MILE	BLUE	ROOF	HILL*
BOOK	MILK*			LEGS	ROSE*			LEGS	ROSE*		
BLUE	ROOF	MILE	HILL*	NOSE	NECK			WEEK	YEAR	HOUR	DAY

B. INFORMATION PRESENTATION RATES

Two presentation rates of $\frac{1}{2}$-bits/sec. and $\frac{1}{4}$-bits/sec. were created by using appropriate presentation times for two-, three-, and four-word items. The presentation time included a period when the stimulus word was present and a blank response time of equal length. These times are shown in Table 5 by item length and information presentation rates.

Table 5

PRESENTATION OF ITEMS BY ITEM LENGTH AND INFORMATION PRESENTATION RATES

ITEM LENGTH	STIMULUS	PRESENTATION TIMES	
		$\frac{1}{2}$-Bit/Sec. Rate	$\frac{1}{4}$-Bit/Sec. Rate
Two Word Items	on	1.0 second	2.0 seconds
	off	1.0 second	2.0 seconds
Three Word Items	on	1.585 seconds	3.170 seconds
	off	1.585 seconds	3.170 seconds
Four Word Items	on	2.0 seconds	4.0 seconds
	off	2.0 seconds	4.0 seconds

C. SUBJECTS

Forty-two graduate level students attending the U.S. Naval Postgraduate School at Monterey, California served as subjects. They were all volunteers and randomly assigned to two treatment groups.

D. EXPERIMENTAL DESIGN

Two treatment groups of 21 subjects each were formed, one for the $\frac{1}{2}$-bit/sec. rate and another for the $\frac{1}{4}$-bit/sec. rate. The experimental design was a mixed, factorial design with item length (three levels), similarity (two levels), and trials (nine trials) being within-subject effects; information presentation rate (two levels) and sequences (three levels) were between-subject effects. (A trial is defined as one complete list presentation to a subject).

E. EQUIPMENTS

The equipment used in the randomized presentation of the item sequence consisted of a Lafayette, high-speed, memory drum connected in series to a timing device as shown on the system diagram in Figure 1 (a more detailed logic flow diagram is included in Appendix A). The tape, as shown in Figure 1, was punched with either the first, second or third column left blank to correspond to having one of three possible word item lengths. The signal sequence corresponded to the sequence of two-, three-, and four-word items shown in Table 6. The tape, when placed into the reader, determined the type of signal (one, two or three). The signal was then interpreted by the logic panel which then triggered the appropriate timing device to engage the memory drum for the required interval. After the memory drum was engaged, a signal was transmitted to the reading device to accept another signal. The same signal was then

Figure 1

Circuit Diagram

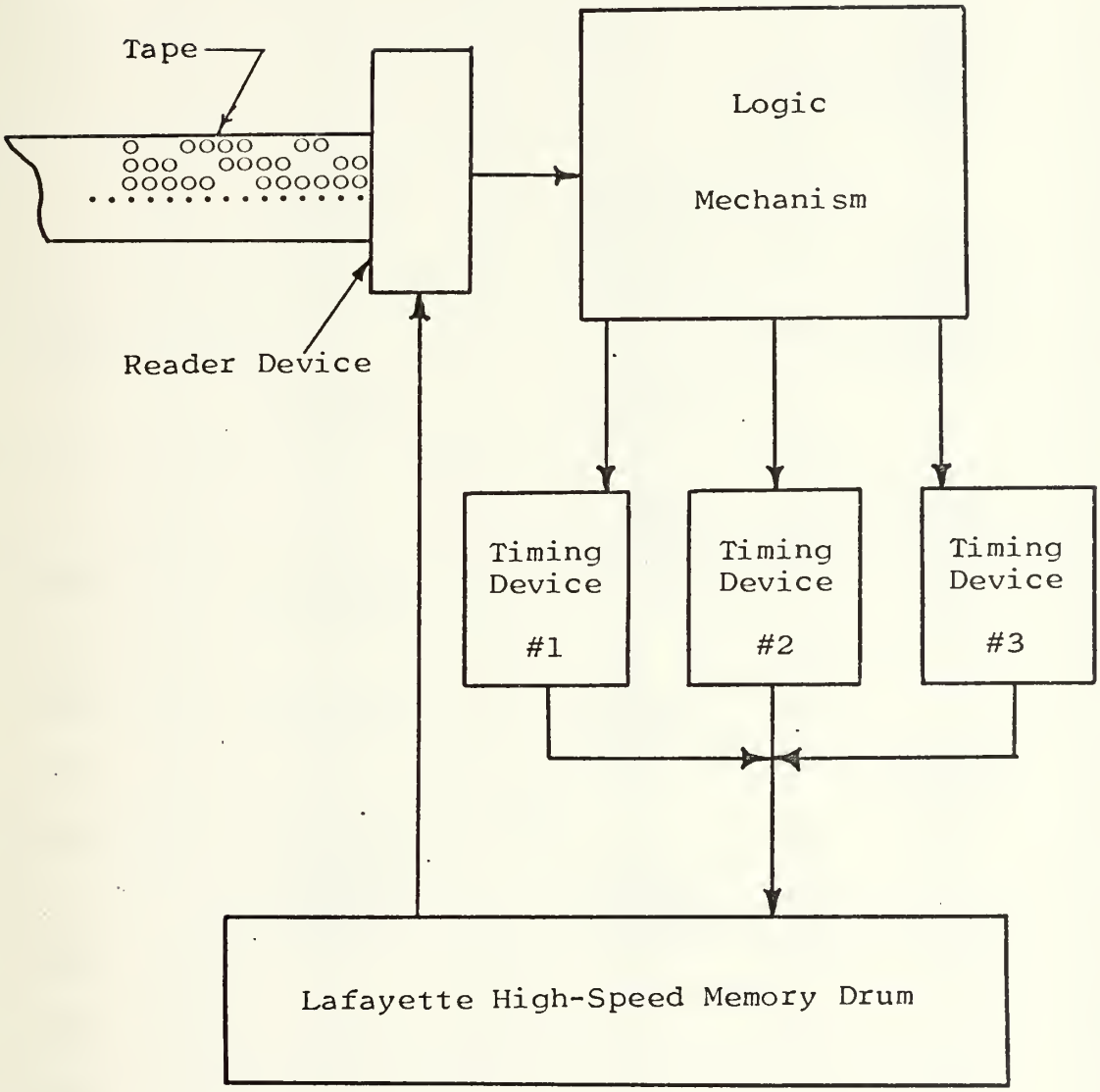


Table 6

TIMING SEQUENCES FOR $\frac{1}{2}$-BIT/SEC. RATE[2]

Item No.	Item Length	Subseq. A1,B1,C1	Item Length	Subseq. A2,B2,C2	Item Length	Subseq. A3,B3,C3	Stim. Words
1.	2	1	4	2	3	1.585	on
		1		2		1.585	off
2.	2	1	2	1	3	1.585	on
		1		1		1.586	off
3.	4	2	2	1	4	2	on
		2		1		2	off
4.	3	1.585	3	1.585	2	1	on
		1.585		1.585		1	off
5.	4	2	3	1.585	3	1.585	on
		2		1.585		1.585	off
6.	2	1	4	2	3	1.585	on
		1		2		1.585	off
7.	3	1.585	3	1.585	2	1	on
		1.585		1.585		1	off
8.	4	2	4	2	4	2	on
		2		2		2	off
9.	2	1	3	1.585	3	1.585	on
		1		1.585		1.585	off
10.	3	1.585	2	1	4	2	on
		1.585		1		2	off
11.	4	2	4	2	2	1	on
		2		2		1	off
12.	3	1.585	3	1.585	2	1	on
		1.585		1.585		1	off
13.	4	2	2	1	3	1.585	on
		2		1		1.585	off
14.	3	1.585	4	2	4	2	on
		1.585		2		2	off
15.	3	1.585	3	1.585	2	1	on
		1.585		1.585		1	off
16.	2	1	4	2	4	2	on
		1		2		2	off
17.	2	1	2	1	2	1	on
		1		1		1	off
18.	4	2	2	1	4	2	on
		2		1		2	off

[2] The timing sequences were exactly the same for the $\frac{1}{4}$-bit/sec. rate except for the fact that presentation times were twice as long. e.g., 2-sec. on and 2-sec. off for a 2-word item.

retransmitted to correspond to the inter-item blank interval and the process continued. The timing devices were appropriately set to correspond to the presentation rates as shown in Table 7.

Table 7

TIMING DEVICE SETTINGS

TIMING DEVICE #	PRESENTATION RATES	
	$\frac{1}{2}$-Bit/Sec.	$\frac{1}{4}$-Bit/Sec.
1	1 second	2 seconds
2	1.585 seconds	3.17 seconds
3	2 seconds	4 seconds

F. CONDITIONS AND PROCEDURES

The subjects were run individually in a sound-attenuated chamber which also contained the experimenter and memory drum. The selection and timing equipment were located external to the chamber.

Prior to each test, the subject was read a set of instructions on the task and the procedures (Appendix B). The subjects were then tested by being exposed to the appropriate word sequence for a total of nine trials. The word sequence was selected randomly without replacement and

with the constraint that each sequence had to be equally represented in each rate group. Therefore, the sequence A, for example, with its three subsequences A-1, A-2, and A-3 was repeated three times for one subject. The subject was required to announce the word he believed to be the correct or appropriate response during the trials.

The items were presented for a fixed time interval corresponding to the number of words contained in the item. This was followed by an inter-item blank interval of the same duration (see Table 6). If the subject's response was correct, the experimenter utilized the contingent reinforcement method by responding "correct".

The subject's responses were then recorded and formed into the basic data for the analysis. No additional time was given between trials.

III. RESULTS

The results of this experiment will first be analyzed according to the growth of the number of correct responses made throughout nine trials; then analysis will be made in terms of the decrease in the amount of uncertainty remaining. The number of correct responses for each of the subjects in the different groups are as tabulated in Appendices C and D in terms of the relevant variables. The relevant variables are: Rates, Sequence, Trials, Word Item Length, and Similarity/Dissimilarity.

The mean number of correct responses per trial at both presentation rates ($\frac{1}{2}$-bits/sec. and $\frac{1}{4}$-bits/sec.) are presented in Tables 8 and 9. Figures 2 and 3 are the respective graphical representations. The mean number of correct responses per item length per trial over both presentation rates is given in Table 10 and pictured in Figure 4. Table 11 and Figure 5 provide a direct comparison of the learning of the group presented the faster rate ($\frac{1}{2}$-bits/sec.) with the group presented the slower rate ($\frac{1}{4}$-bits/sec.).

Table 8

MEAN NUMBER OF CORRECT RESPONSES AT A PRESENTATION RATE OF $\frac{1}{2}$-BITS/SEC. PER ITEM LENGTH

TRIALS	2 WORD ITEM	3 WORD ITEM	4 WORD ITEM
1	3.0953	1.9524	1.8095
2	3.2381	2.1908	1.9048
3	3.8095	2.6667	1.9524
4	3.8571	3.3810	2.5714
5	4.4286	3.3333	2.6667
6	4.3333	3.5714	2.6667
7	4.2381	3.6667	2.8095
8	4.2381	4.1428	3.0000
9	4.6190	4.3333	2.9048

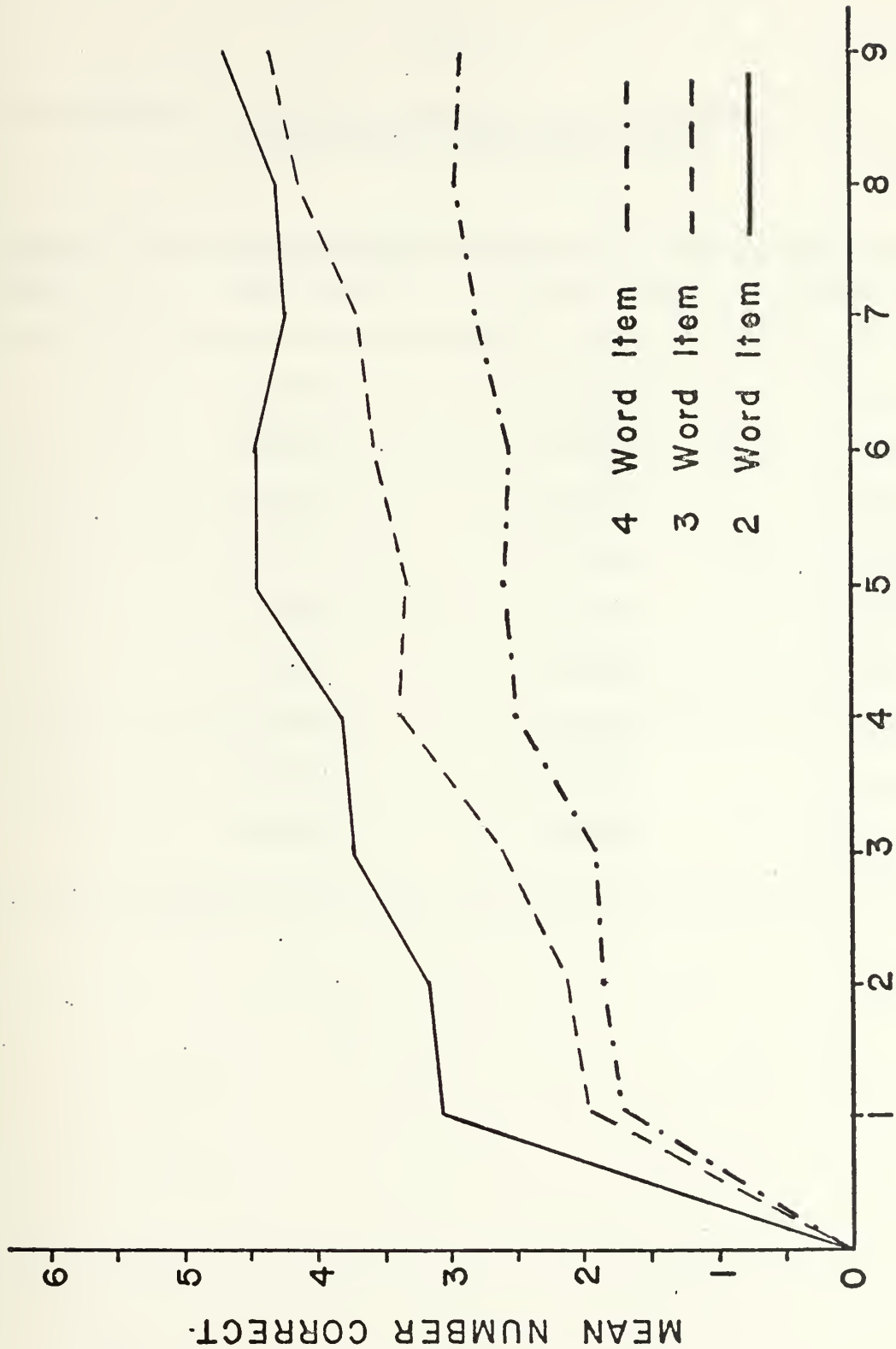


FIGURE 2. Mean Number of Correct Responses at a Presentation Rate of 1/2 - Bits/Sec. per Item Length.

Table 9

MEAN NUMBER OF CORRECT RESPONSES AT A PRESENTATION RATE OF $\frac{1}{4}$-BIT/SEC. PER ITEM LENGTH

TRIALS	2 WORD ITEM	3 WORD ITEM	4 WORD ITEM
1	2.8571	2.4286	1.5238
2	4.2381	2.2143	1.6667
3	4.4286	2.9048	2.1905
4	4.7619	3.9524	2.9048
5	5.0000	4.0952	3.2857
6	5.0000	4.4286	3.7619
7	5.2857	4.7143	4.4762
8	5.8095	5.2381	4.6667
9	5.6667	5.4286	5.0476

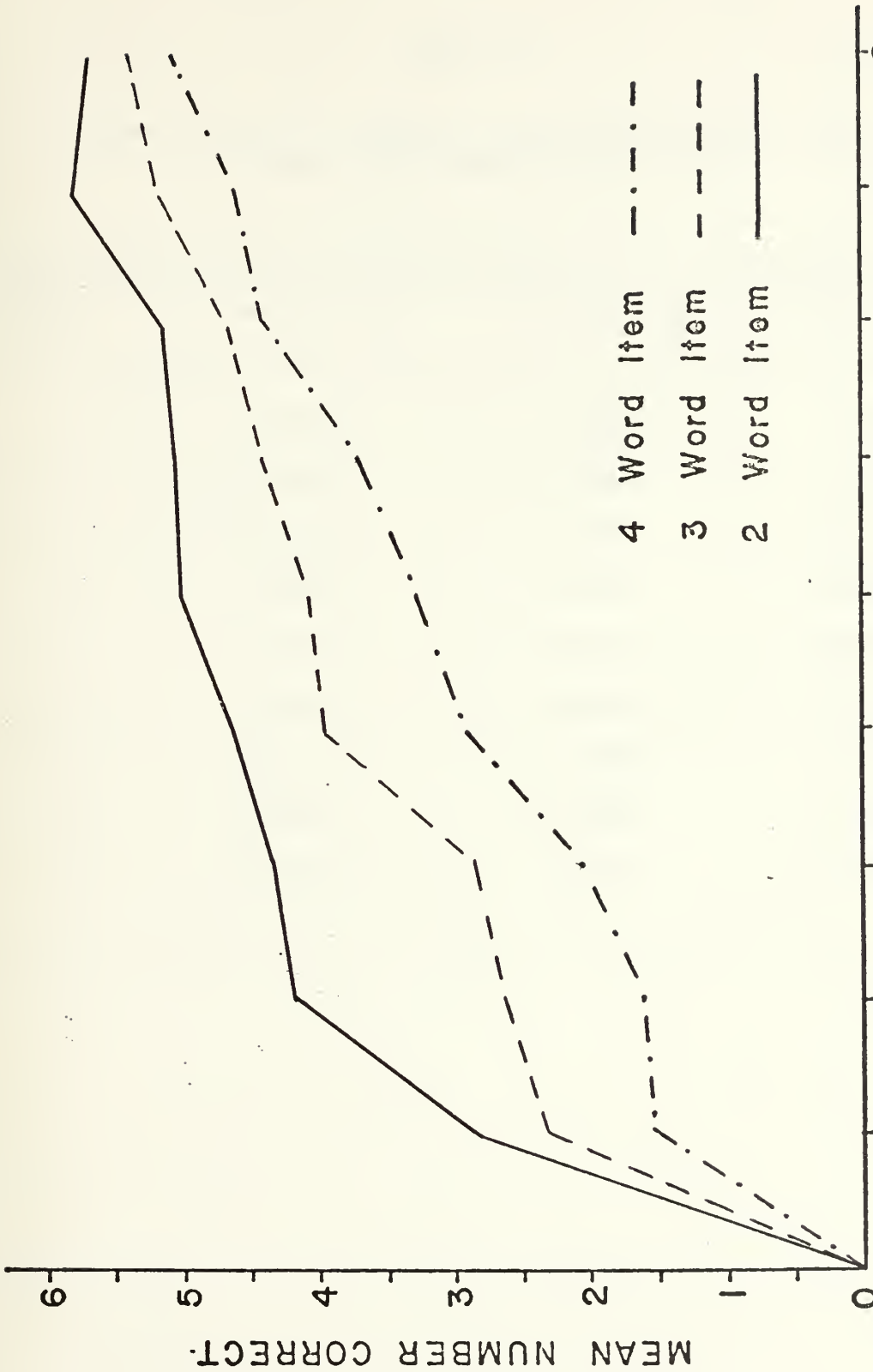


FIGURE 3. Mean Number of Correct Responses at a Presentation Rate of 1/4-Bits/Sec. per Item Length.

Table 10

MEAN NUMBER OF CORRECT RESPONSES PER ITEM LENGTH
OVER BOTH PRESENTATION RATES

TRIALS	2 WORD ITEM	3 WORD ITEM	4 WORD ITEM
1	2.9762	2.1905	1.6667
2	3.7381	2.4524	1.7857
3	4.1190	2.7857	2.0714
4	4.3095	3.6667	2.7381
5	4.7143	3.7143	2.9762
6	4.6667	4.0000	3.2143
7	4.7619	4.1905	3.6428
8	5.0238	4.6905	3.8333
9	5.1428	4.8809	3.9762

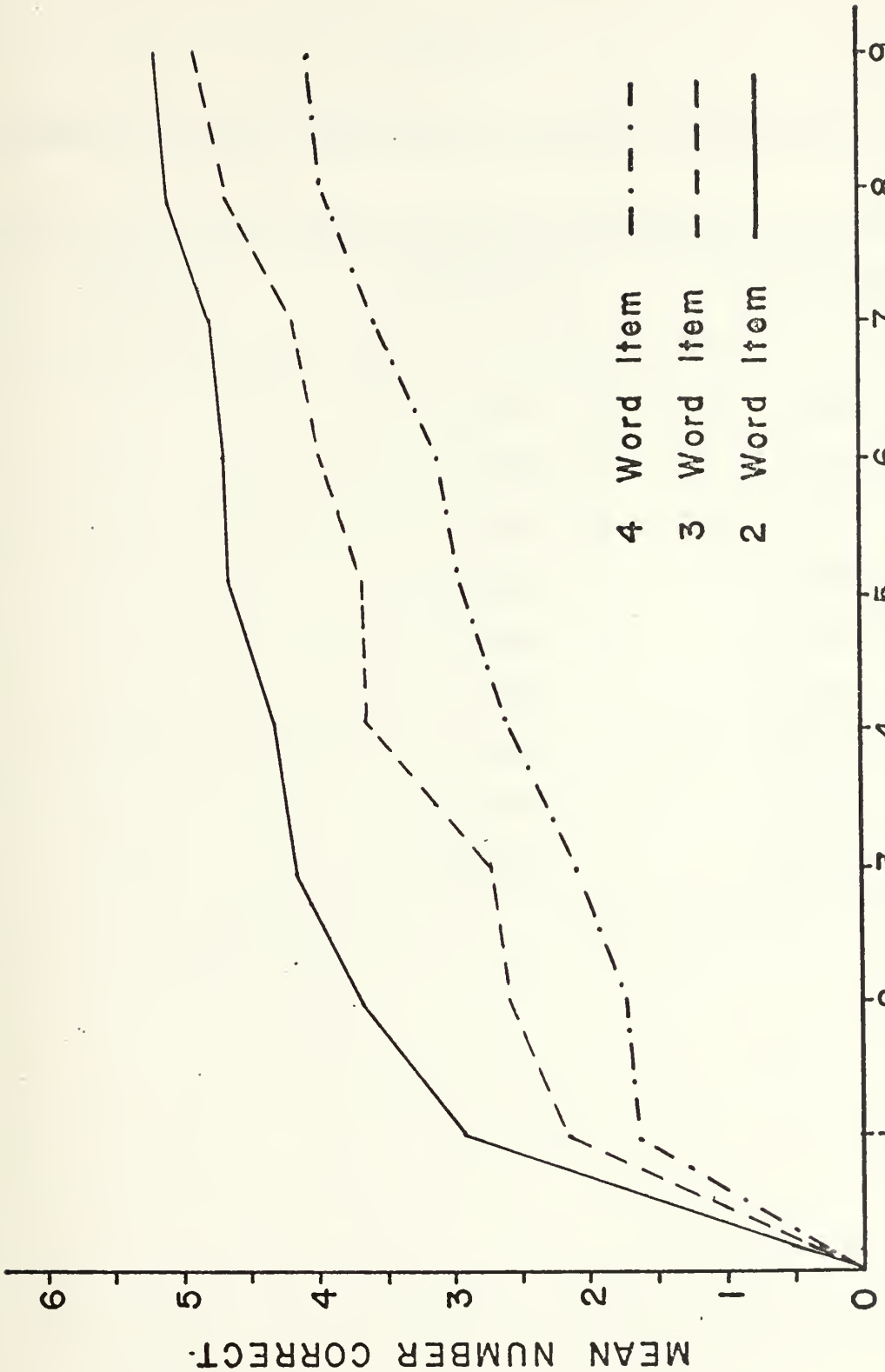


FIGURE 4. Mean Number of Correct Responses per Item Length over both Presentation Rates.

Table 11

NUMBER OF CORRECT RESPONSES AT THE TWO PRESENTATION RATES

TRIALS	$\frac{1}{2}$-BITS/SEC.	$\frac{1}{4}$-BITS/SEC.
1	2.2857	2.2698
2	2.4444	2.8730
3	2.8095	3.1746
4	3.2698	3.8730
5	3.4762	4.1270
6	3.5238	4.3968
7	3.5714	4.8254
8	3.7936	5.2381
9	3.9524	5.3810

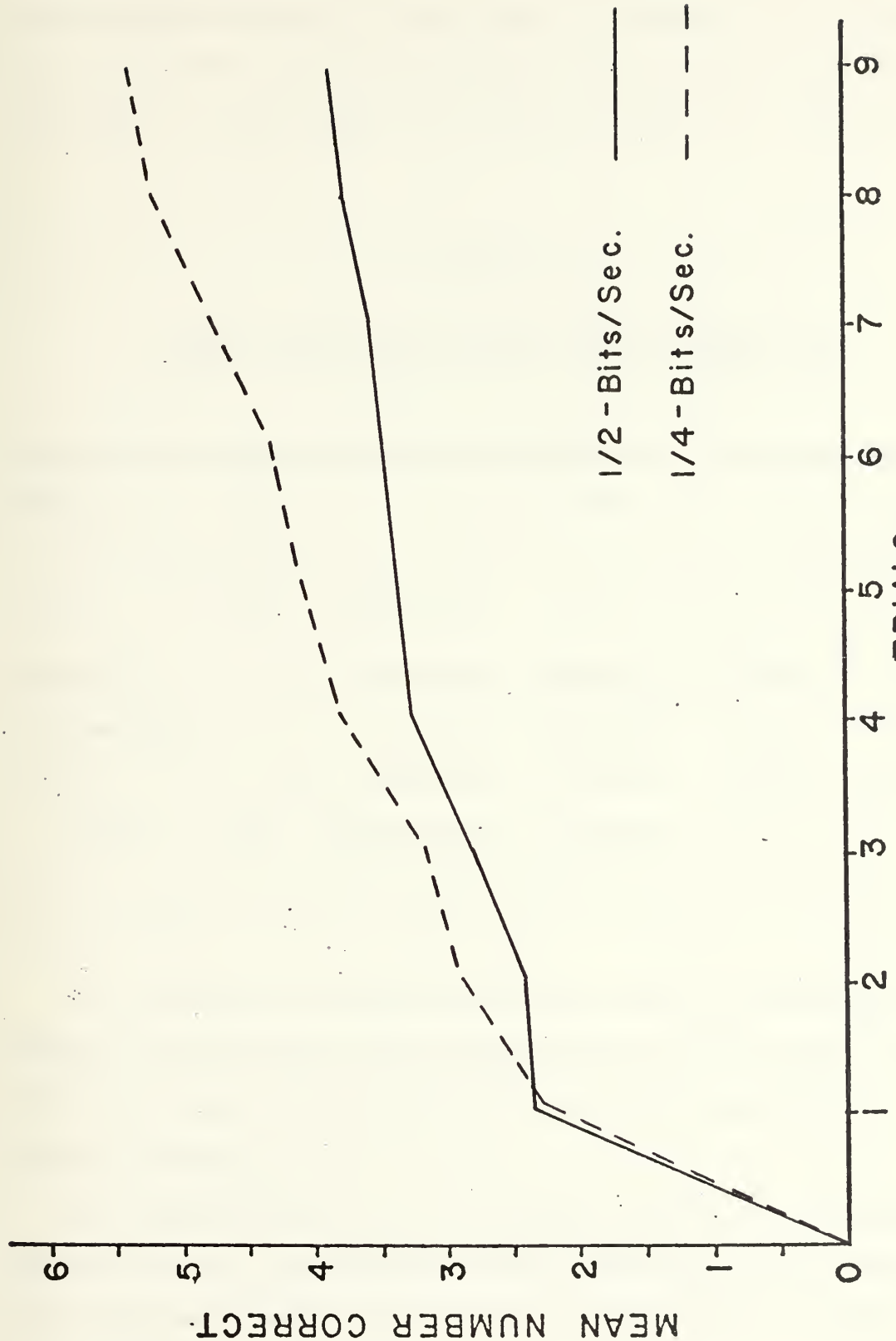


FIGURE 5. Comparison of the Number of Correct Responses at the two Presentation Rates.

Since the use of the sequences A, B, and C were evenly distributed between the two rates, an analysis of variance was conducted to determine whether the sequence type had any effect on the number of correct responses. (Table 12).

Table 12

ANALYSIS OF VARIANCE OF THE NUMBER OF CORRECT RESPONSES BY RATE AND SEQUENCE TYPE

SOURCE	df	ss	ms	f	p
Total	1133	2910.2143	--------	-------	
Rate(R)	1	173.0590	173.0590	72.7719	$<.001$
Sequence(S)	2	42.4814	21.2407	8.9317	$<.001$
R x S	2	12.1500	6.0750	2.5545	$.05<p<.10$
Error	1128	2682.5239	2.3781	------	

The analysis indicated that both rate (as expected) and sequence type proved to be significant at the $p<.001$ level while the rate x sequence interaction was significant at the $.05<p<.10$ level.

The significance of the sequence type was not expected since the three sequences had the same words, the order of the items was random, and each had the identical timing sequence. The interaction approaches significance due

primarily to the high performance of subjects using sequence C in the $\frac{1}{4}$-bits/sec. group. (Table 13 shows the mean number of correct responses as tabled by rate and by sequence type.)

Table 13

MEAN NUMBER OF CORRECT RESPONSES
BY RATE AND SEQUENCE

RATE	SEQUENCE		
	A	B	C
$\frac{1}{2}$-bits/sec.	3.1164	3.2380	3.3544
$\frac{1}{4}$-bits/sec.	3.7513	3.8730	4.4285

The results indicate that the group undergoing sequence C did better than those undergoing sequence B and similarly, those with sequence B did better than those undergoing sequence A.

For purpose of further analysis the sequence variable will not be included, since as indicated earlier, the effect of the sequence type is evenly distributed between the two rates of presentation and the interaction of rates by sequence reached only marginal statistical significance.

Concerning the analysis of variance of the number of correct responses, Table 14 indicated that when subjects are presented a random mixed sequence of two-, three-, and

four-word items, the variables rate of presentation, item lengths, and trials are still a significant factor at the $p = 0.001$ level.

Table 14

ANALYSIS OF VARIANCE OF THE NUMBER OF CORRECT RESPONSES

SOURCE	SS	df	MS	F	P
TOTAL	2155.8626	2267	-------	-------	-----
Between Subjects	255.6072	41	-------	-------	-----
Rate(R)	86.5295	1	86.5295	20.4711	<.001
$Error_b$	169.0777	40	4.2269		
Within Subjects	1900.2554	2226	-------	-------	-----
Similarity(S)	4.3214	1	4.3214	2.6949	<.20
R x S	1.1469	1	1.1469	.7152	n.s.
$Error_1$	64.1428	40	1.6035		
Trials(T)	346.7064	8	43.3383	87.9786	<.001
R x T	32.6411	8	4.0801	8.2827	<.001
$Error_2$	157.6525	320	.4926		
Word Item Length(L)	214.1353	2	107.0677	57.1210	<.001
R x L	.1275	2	.0638	.0340	n.s.
$Error_3$	149.9594	80	1.8744		
S x T	4.1986	8	.5248	1.2383	n.s.
R x S x T	2.0559	8	.2570	.6064	n.s.
$Error_4$	135.6344	320	.4238		
S x L	9.0816	2	4.5408	2.5558	<.01
R x S x L	2.7864	2	1.3932	.7841	n.s.
$Error_5$	142.1320	80	1.7766		
T x L	15.9441	16	.9965	2.2408	<.008
R x T x L	14.1905	16	.8869	1.9943	<.01
$Error_6$	284.6432	640	.4447		
S x T x L	10.9346	16	.6834	1.5013	<.1
R x S x T x L	16.7370	16	1.0461	2.2981	<.008
$Error_7$	291.3295	640	.4552		

The similarity/dissimilarity main effect was not significant ($p<.20$). The significant interactions were: rate x trials at $p = .001$ level and similarity /dissimilarity x

item length, trials x item length, rate x trial x item length, similarity/dissimilarity x item length x trial and finally the rate x similarity x item length x trial interactions at $p < .01$ level.

The significance of the similarity/dissimilarity x item length interaction is due in part to the larger number of correct responses in the case of word items consisting of similar words as the item lengths increase. (See Table 15).

Table 15

NUMBER OF CORRECT RESPONSES BY SIMILARITY/DISSIMILARITY AND ITEM LENGTH

ITEM LENGTH	SIMILARITY	DISSIMILARITY
2	815	842
3	729	639
4	562	526

In order to proceed with the information analysis, the hypothesis of initial equally-likely alternatives was first tested using the chi-square test. This was accomplished by arbitrarily designating each word within an item as number 1, 2, 3, or 4 depending on the number of words in the item. (See Appendices F, G, and H). The first-trial choices for all 42 subjects were then tallied and totaled by item length. (See Table 16). The resulting first-choice distribution was

then tested against a hypothetical equally-likely first-choice distribution. The resulting chi-square values (Table 16) failed to exceed the tabled values of chi-square for 3 d.f. (7.81), 2 d.f. (5.99), and 1 d.f. (3.84) at the p = .05 level of significance.

Table 16

OBTAINED VERSUS EXPECTED DISTRIBUTION OF FIRST CHOICES BY ITEM LENGTH

ITEM LENGTH	EXPECTED PER WORD	WORD 1	WORD 2	WORD 3	WORD 4	CHI-SQUARE STATISTIC
4-word	63	69.0	54.0	63.0	66.0	1.999
3-word	84	96.0	68.0	88.0		4.9524
2-word	126	125.0	127.0			.1587

Accordingly the chi-square test resulted in acceptance of the null hypothesis of equally likely alternatives (at the p = .05 level) in the initial distribution of choices.

The amount of information processed on each trial was determined by, first of all, tabulating all the possible permutation of choices for the two-, three-, and four-word items by blocks of two trials and determining the total bits of information contained in each permutation. (See Appendices I, J, and K). The amount of uncertainty remaining after each block of two trials was then obtained for each subject for the two-, three-, and four-word items. In

order to facilitate the analysis of the amount of uncertainty remaining and since the number of similar/dissimilar word items were evenly distributed in any given word sequence, the variable was disregarded during this phase of the analysis. The resulting data base of total bits of uncertainty remaining for each subject as a function of blocks is tabulated in Appendix D.

In the information analysis phase, the amount of uncertainty associated with two- and three- word items was normalized with respect to the four-word items in order to have a common base of 12 bits of uncertainty at the start of learning regardless of the item type. This was done by multiplying the amount of uncertainty for each two-word item by two and each three-word item by 1.2631. (The computer program shown in Appendix E was used for this transformation.) Tables 17 and 18 show the average amount of uncertainty remaining at each block of trials as a function of word-item length and presentation rates of $\frac{1}{2}$-bit/sec. and $\frac{1}{4}$-bit/sec., respectively. Figures 6 and 7 are graphical representations. Table 19 presents the amount of uncertainty remaining at each block of trials with respect to the word-item lengths. The graphical representation is in Figure 8. Table 20 is a direct comparison of the uncertainty remaining at each block of trials with respect to the two presentation rates of $\frac{1}{2}$-bit/sec. and $\frac{1}{4}$-bit/sec. Figure 9 shows that, starting from an initial total amount of uncertainty of 36 bits, there is a steady decrease in

Table 17

AVERAGE AMOUNT OF UNCERTAINTY REMAINING BY BLOCKS FOR WORD ITEM LENGTHS PRESENTED AT $\frac{1}{2}$-BITS/SEC.

BLOCKS	2-WORD ITEMS	3-WORD ITEMS	4-WORD ITEMS
1	10.6884	10.8392	10.5500
2	9.8696	10.3705	9.7290
3	9.2388	8.8980	9.7491
4	9.2404	8.4463	8.8059

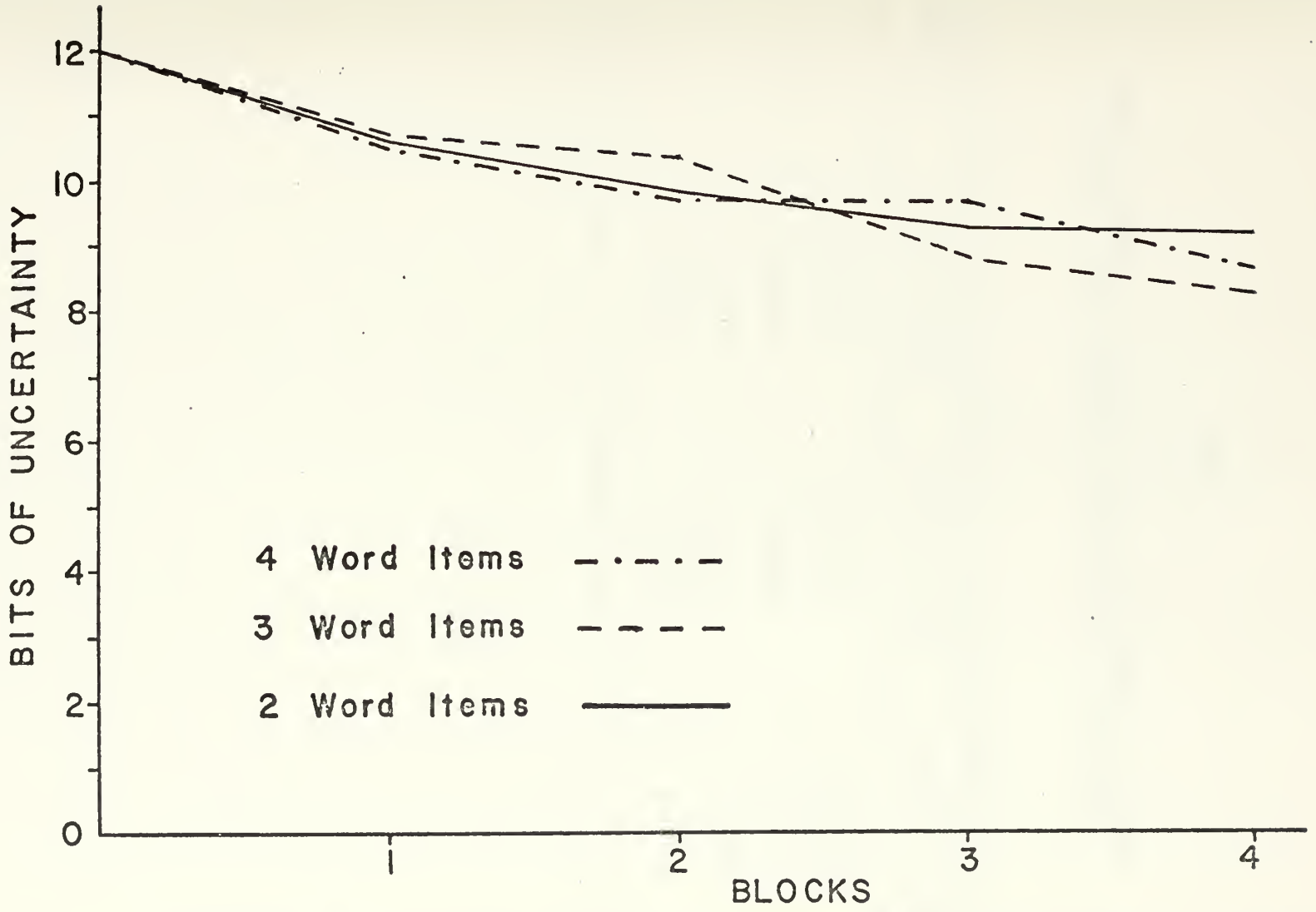


FIGURE 6. Average Amount of Uncertainty Remaining by Blocks for Word Item Lengths Presented at 1/2-Bits/Sec.

Table 18

AVERAGE AMOUNT OF UNCERTAINTY REMAINING BY BLOCKS FOR WORD ITEM LENGTHS PRESENTED AT $\frac{1}{4}$-BITS/SEC.

BLOCKS	2-WORD ITEMS	3-WORD ITEMS	4-WORD ITEMS
1	11.2200	11.2918	10.7555
2	8.6662	9.8821	9.9773
3	6.6230	6.9442	8.2689
4	3.4780	4.8145	4.9672

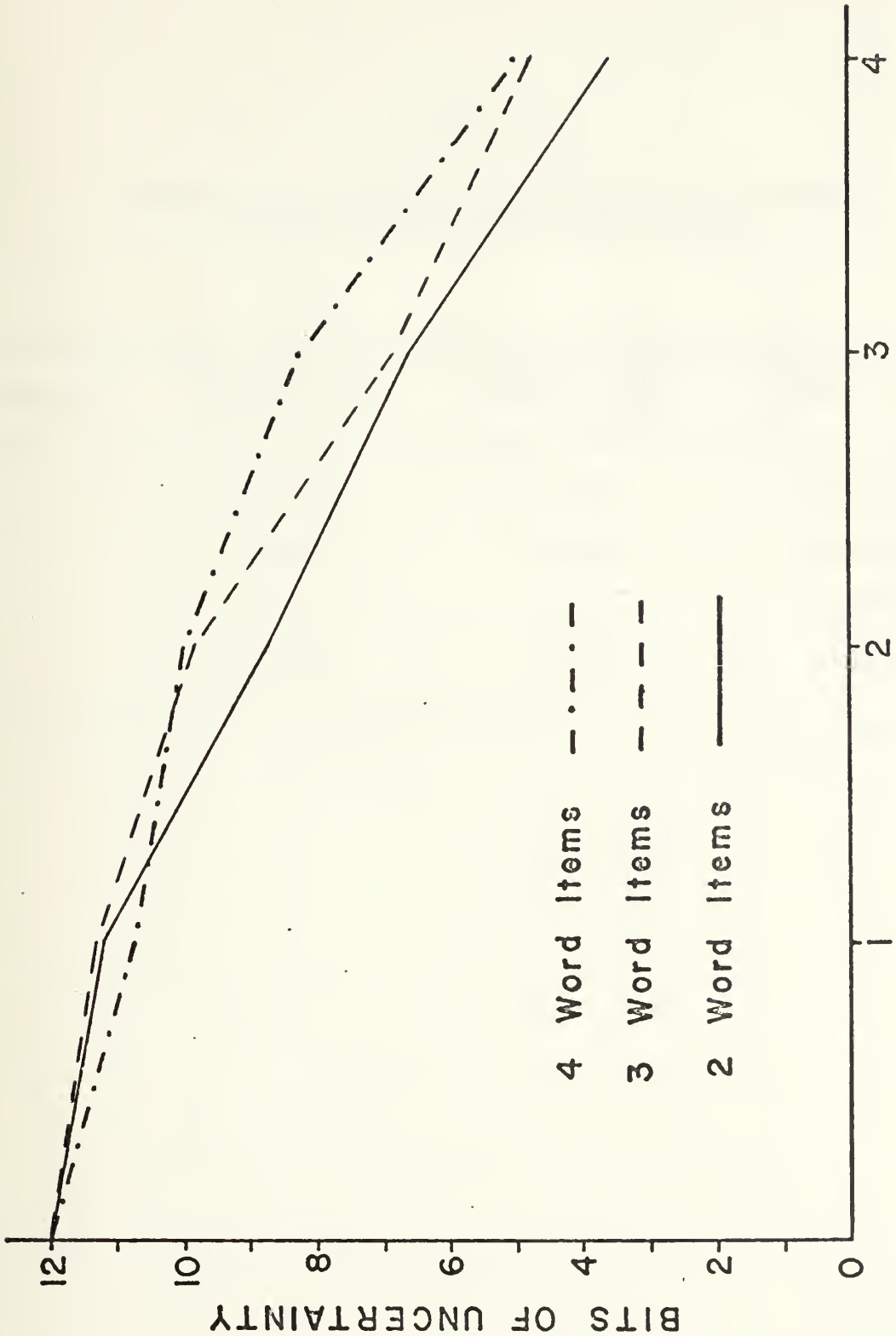


FIGURE 7. Average Amount of Uncertainty Remaining by Blocks for Word Item Lengths Presented at 1/4-Bits/Sec.

Table 19

AVERAGE TOTAL AMOUNT OF UNCERTAINTY REMAINING
BY BLOCKS AND WORD ITEM LENGTHS

BLOCKS	2-WORD ITEMS	3-WORD ITEMS	4-WORD ITEMS
1	10.9546	11.0655	10.6528
2	9.2678	10.1263	9.9484
3	7.9310	7.9210	9.0090
4	6.3592	6.6304	6.8866

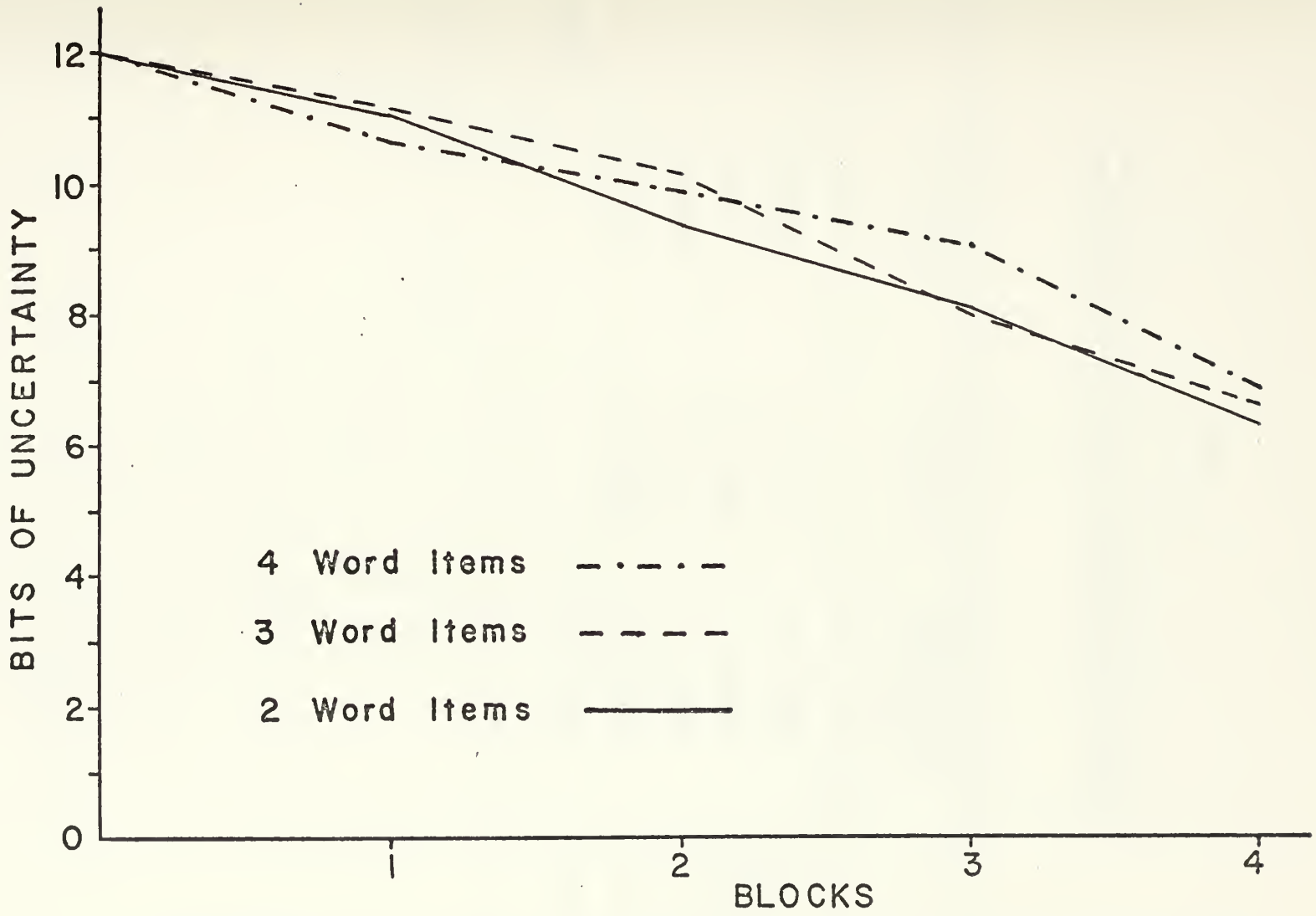


FIGURE 8. Average Total Amount of Uncertainty Remaining by Blocks and Word Item Lengths.

Table 20

AVERAGE TOTAL AMOUNT OF UNCERTAINTY REMAINING
BY BLOCKS AND THE TWO PRESENTATION RATES

Blocks	$\frac{1}{2}$-Bits/Sec. (Y)	$\frac{1}{4}$-Bits/Sec. (X)	Predicted* $\frac{1}{2}$-Bits/Sec. ($\hat{Y}$)	$\lvert Y-\hat{Y} \rvert$
1	32.0886	33.2796	34.6398	2.5512
2	30.1700	28.5356	32.2678	2.0978
3	27.8950	21.8429	28.9214	1.0264
4	26.7870	13.2646	24.6323	2.1547
Mean			30.1153	1.9575

* $\hat{Y} = \frac{1}{2}(36.0 - X) + X$

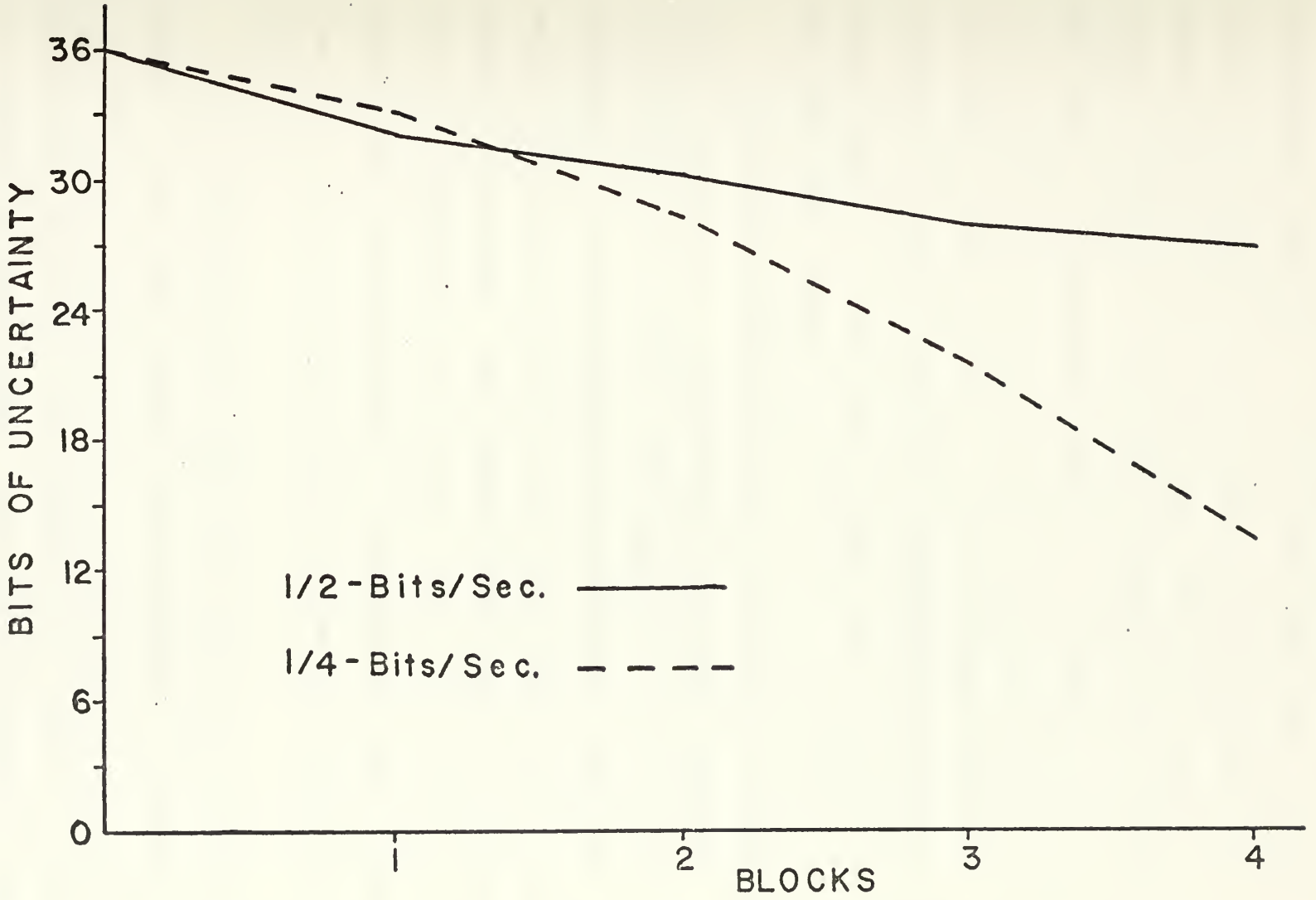


FIGURE 9. Average Total Amount of Uncertainty Remaining by Blocks and the two Presentation Rates.

uncertainty. After the second block, however, the slower presentation rate shows a much larger decrease in the uncertainty remaining. On the basis that the $\frac{1}{2}$-bit/sec. group was presented twice as much information per unit of time compared with the $\frac{1}{4}$-bit/sec. group, an attempt was made to predict the $\frac{1}{2}$-bit/sec. performance from the $\frac{1}{4}$-bit/sec. data. The equation used was $Y = \frac{1}{2}(36.0 - X) + X$. The predicted performance is also shown in Table 20. From the ratio of the mean of $|Y - \hat{Y}|$ to the mean predicted value, a 6.5 percent error was obtained in forecasting the performance of the $\frac{1}{2}$-bit/sec. group from the performance of the $\frac{1}{4}$-bit/sec. group.

The normalized data were then analyzed by a modification of the three-factor, mixed design experiment shown in Bruming and Kintz (1968). The experiment conforms to a three-factor, mixed design with rates being a between subjects variable and blocks and item lengths being within subjects variables. The results (see Table 21) indicate that the variables rates, blocks, and rates x blocks interaction were all significant at the $p < .001$ level; whereas the blocks x item length interaction was not significant ($p \cong .10$).

The presentation rate main effect was to be expected, since only one-half the time was available to process the same amount of information in the $\frac{1}{2}$-bit/sec. group. The blocks main effect was also expected as a learning effect. In information theory terms, this would correspond to the

Table 21

ANALYSIS OF VARIANCE OF UNCERTAINTY REMAINING

SOURCE	SS	df	MS	F	P
TOTAL	5576.9492	503	--------	-------	-----
Between Subjects	1323.3047	41	--------	-------	-----
Rate(R)	350.6224	1	350.6224	14.4188	<.001
Error_b	972.6824	40	24.3170		
Within Subjects	4253.6445	462	--------	-------	-----
Blocks(B)	1270.3478	3	423.4492	75.1409	<.001
R x B	431.8829	3	143.9610	25.5458	<.001
Error_1	676.2578	120	5.6354		
Item Length(L)	18.0854	2	9.0427	.8246	n.s.
R x L	28.3410	2	14.1705	1.2923	n.s.
Error_2	877.2258	80	10.9653		
B x L	39.2563	6	6.5427	1.7700	<.10
R x B x L	25.1138	6	4.1856	1.1323	n.s.
Error_3	887.1337	240	3.6963		

transfer of information from the unlearned to learned state. The rate by blocks interaction is seen in Figure 9 by the relative increase in the amount of information processed by the $\frac{1}{2}$-bit/sec. group as a function of blocks. This nonlinear divergence of the curves was also to be expected because the time factor of 2 between the two presentation rates is multiplicative. That is, as learning increases, the difference in the amount of information processed should also increase between the two groups.

The nonsignificance of the item-length main effect and the interactions of item-length with rate and blocks is the crucial finding of this experiment. It indicates that a single subject learns two-, three-, and four-word items at the same information processing rate and that this finding is true when the information presentation rates differ by a factor as great as two.

IV. DISCUSSION

This experiment of presenting a mixture of VD items of different lengths in a random sequence generally substantiated the results found by Baltutis (1972) and the expectations from information theory.

The analysis of the number of correct responses under various conditions indicated that word item length, rates, and trials main effects are significant; whereas, in the analysis of the amount of uncertainty only blocks and rates main effects were found to be significant.

The results indicate that, regardless of the method of presenting individual subjects verbal tasks for learning, tasks involving less alternatives for choices, that is, smaller in quantity of initial bits of uncertainty, would not necessarily be learned at a faster rate. The results clearly indicate that two-word items were, in fact, learned sooner than were three- or four-word items as one would expect since an initial right or wrong (unreinforced) answer served to identify the correct response. However, when the word items were quantified for information content, the rate at which the word items were learned (information was transferred) indicated a high degree of similarity among all methods (see Table 19 and Figure 8).

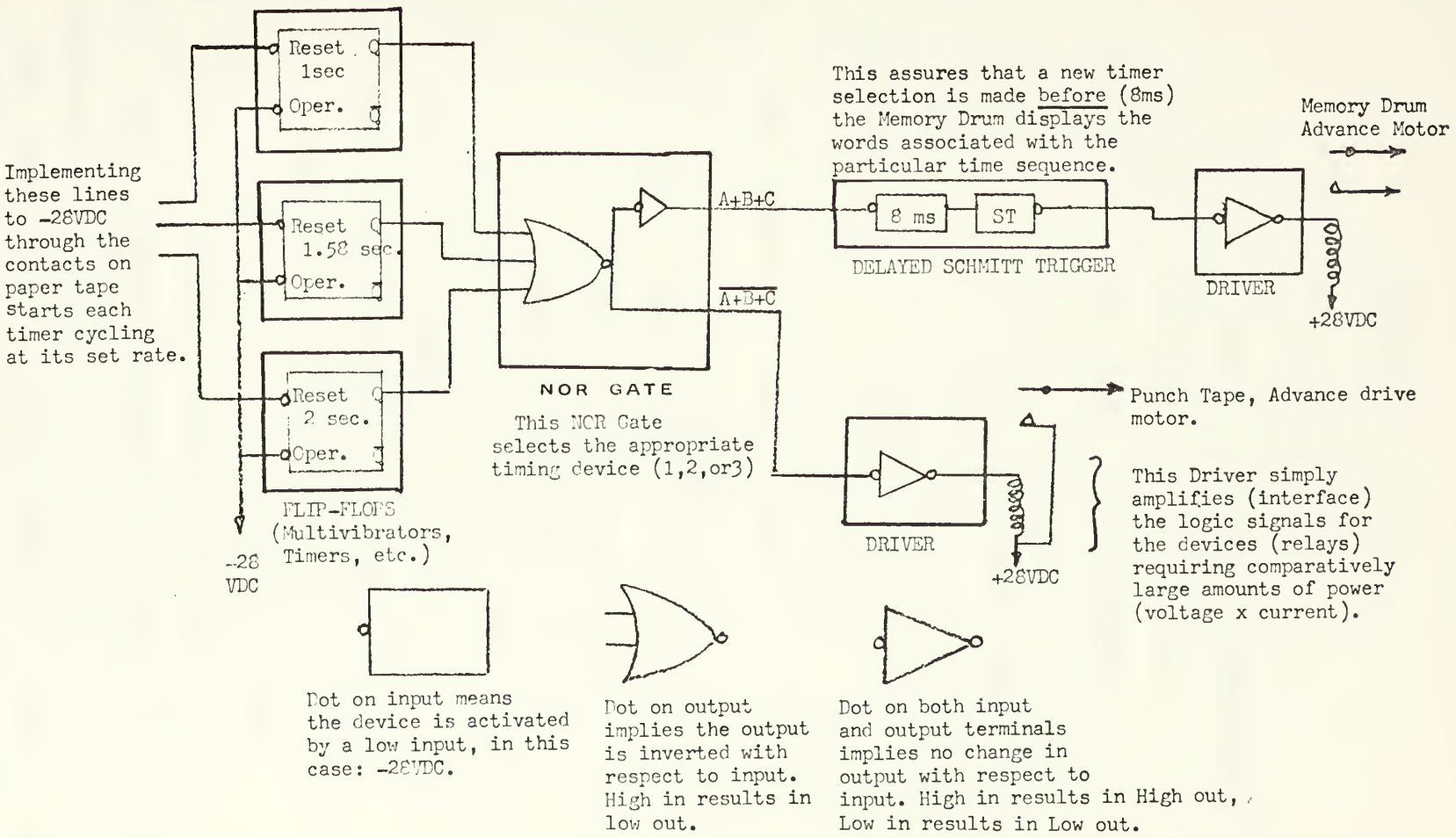
The speed of presentation also affected learning. It was assumed that the slower presentation rate would afford

subjects greater opportunity to view and subsequently rehearse the words within an item and thereby have a greater mean number of correct responses. The results clearly substantiate this.

In discussing the progress of learning, it was predicted that learning and the decrease in the amount of uncertainty remaining as a function of the repeated trials would in fact occur. The results also show that this did, in fact, occur.

Appendix A

LOGIC FLOW DIAGRAM



Appendix B

SUBJECT'S INSTRUCTIONS

You are about to participate in a verbal discrimination experiment. During the experiment you will be shown 18 groups of words called items; each item consists of 2-, 3-, or 4-words. In every case one of the words in the item has arbitrarily been selected as a "correct" response for that group. The occurrence of the items are randomly mixed and will be shown to you at a predetermined length of time followed by a blank space of the same duration. You will be given a longer length of time to view a 4-word item as compared to a 3-word item and similarly for a 2-word item.

It is your task to view the words in each item and guess which one is "correct". Once you have made a choice, announce it to the experimenter. If your response is "correct", the experimenter will tell you that you are "correct"; otherwise, no answer will be given. In each item, the "correct" response word will remain the same throughout the experiment. Your objective is to identify as many correct responses as possible on each trial.

Each time we go through the list the items will be in a different order and the position of the words will also vary. Consequently, do not try to remember the correct words by their position in a list or item. Do not let your attention stray from the screen. If you are inattentive or

do not learn the list as quickly as possible, your data will not be useful to us.

Since one of the words in a given item is always correct, you are to choose one and only one when an item is presented. Even on the first trial you are to guess which is correct and to say it aloud before the next item or group of words are viewed.

On the second trial you will be able to make better guesses but, in any case, you must say one of the words of the item every time an item appears.

If you are unable to get many correct after only a few trials, do not permit this to discourage you or to prevent you from trying to learn as many as possible on that and on succeeding trials.

Do you have any questions? If not, relax and await the experimenter's command to begin.

I wish to thank you for your assistance and would appreciate it if you would not discuss this experiment with other students who might participate in this study.

Appendix C

NUMBER OF CORRECT RESPONSES FOR EACH SUBJECT PER TRIAL BY SIMILARITY/DISSIMILARITY AND ITEM LENGHT

SEQUENCE A 1/2 BITS/SEC.

	TRIALS																				
	SIMILAR																				
	1			2			3			4			5			6			7			8			9		
SUBJECTS	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4
1	1	1	0	0	1	2	2	2	2	2	1	2	2	3	1	1	3	1	2	3	1	1	3	2	2	3	1
2	0	0	2	1	2	1	1	1	2	0	3	0	2	3	0	2	3	0	2	3	1	2	3	0	3	3	0
3	3	2	2	3	2	2	3	2	1	3	3	2	3	1	2	2	2	1	2	2	1	2	2	1	1	2	2
4	3	1	0	2	1	2	3	0	1	3	1	0	3	1	2	3	1	0	3	2	0	2	1	0	2	2	1
5	3	1	1	2	2	1	3	1	1	3	2	1	3	0	1	3	1	1	3	1	1	3	1	2	3	3	1
6	1	2	0	2	1	0	1	2	0	2	2	3	2	3	3	2	3	1	1	3	0	3	3	1	3	3	1
7	3	3	0	3	2	0	2	2	1	1	2	0	3	2	1	2	1	0	3	3	0	2	2	0	2	2	0

	TRIALS																				
	DISSIMILAR																				
	1			2			3			4			5			6			7			8			9		
SUBJECTS	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4
1	2	1	0	2	1	0	1	2	1	2	2	1	2	2	1	2	3	2	2	2	2	3	2	1	2	2	2
2	1	2	1	1	1	1	1	1	1	1	1	1	1	2	1	2	1	2	1	1	1	2	1	0	2	1	0
3	2	1	1	2	1	2	2	2	0	2	2	2	1	2	1	1	2	2	1	2	2	0	2	2	1	3	1
4	2	0	1	0	1	1	2	2	0	2	2	0	2	1	0	1	2	0	1	3	0	1	2	2	3	2	0
5	2	2	1	2	1	0	2	2	1	3	1	0	3	3	2	3	1	0	3	2	2	3	1	2	3	2	1
6	1	1	1	2	2	0	2	2	1	2	2	1	2	0	1	2	0	1	2	1	0	2	1	1	2	2	2
7	2	0	2	1	1	2	1	1	2	2	0	1	2	0	1	2	1	2	3	2	1	0	3	1	2	1	1

NUMBER OF CORRECT RESPONSES FOR EACH SUBJECT
PER TRIAL BY SIMILARITY/DISSIMILARITY AND ITEM LENGHT

SEQUENCE B 1/2 BITS/SEC.

	TRIALS																								
	SIMILAR																DISSIMILAR								
	1		2		3		4		5		6		7		8		9		1		2		3		4		5		6		7		8		9	
SUBJECTS	2	3 4	2	3 4	2	3 4	2	3 4	2	3 4	2	3 4	2	3 4	2	3 4	2	3 4	2	3 4	2	3 4	2	3 4	2	3 4	2	3 4	2	3 4	2	3 4	2	3 4
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4	1	1 1	0	1 2	1	0 1	1	2 1	2	1 1	3	2 3	2	2 1	3	2 3	3	2 2	1	2 1	0	1 1	3	2 3	2	1 3	1	2 3	2	2 2	3	1 2	3	3 2	3	2 2
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7	1	0 1	0	1 3	2	2 1	1	2 2	3	1 2	1	3 2	2	3 0	2	1 1	1	2 1	2	1 1	2	1 1	2	1 1	1	1 1	3	1 0	3	1 0	2	0 2	2	3 1	2	1 2

NUMBER OF CORRECT RESPONSES FOR EACH SUBJECT
PER TRIAL BY SIMILARITY/DISSIMILARITY AND ITEM LENGHT

SEQUENCE C 1/2 BITS/SEC.

	TRIALS																																
	SIMILAR																				DISSIMILAR												
	1			2			3			4			5			6			7			8			9			1			2			3		
SUBJECTS	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4
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3	0	1	1	1	1	2	1	2	1	2	3	1	3	3	1	2	3	3	1	3	2	2	3	2	2	3	2	2	1	0	2	1	0	3	2	0
4	1	1	1	1	0	0	2	1	0	2	2	0	2	1	1	3	1	1	3	1	1	1	2	1	2	3	1	2	1	0	3	1	1	2	2	0
5	2	0	0	2	1	0	3	0	0	3	1	1	3	1	0	3	1	1	3	1	1	3	2	2	3	2	1	2	0	1	2	1	0	3	3	2
6	2	3	1	1	3	1	3	3	1	3	2	1	2	3	1	3	3	2	2	3	2	3	3	3	3	3	3	1	2	1	2	2	1	3	2	3
7	3	0	2	2	2	2	3	0	1	3	2	2	2	1	2	3	2	1	3	1	2	2	3	2	2	2	1	2	0	1	3	0	1	3	0	2

NUMBER OF CORRECT RESPONSES FOR EACH SUBJECT
PER TRIAL BY SIMILARITY/DISSIMILARITY AND ITEM LENGHT

SEQUENCE A 1/4 BITS/SEC.

	TRIALS																																
	SIMILAR																				DISSIMILAR												
	1			2			3			4			5			6			7			8			9			1			2			3		
SUBJECTS	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4
1	3	2	1	2	1	1	2	2	1	3	2	1	2	3	1	3	3	1	3	3	1	3	3	1	3	3	1	2	1	0	2	1	1	2	1	2
2	1	2	2	2	1	2	1	2	0	2	3	2	3	3	1	2	3	1	2	3	2	3	3	2	3	3	3	1	2	1	2	2	1	2	2	1
3	0	1	1	2	2	1	2	1	2	2	2	1	2	1	1	2	2	1	2	1	0	3	3	0	3	2	1	1	1	0	3	1	0	3	1	0
4	3	1	0	1	1	1	3	0	1	3	0	1	2	0	2	3	0	2	3	1	2	2	1	3	2	2	3	1	3	0	3	2	1	2	2	0
5	3	1	1	2	2	0	2	3	1	3	2	2	3	2	3	2	3	2	3	3	2	2	3	3	3	3	3	1	2	0	3	0	1	3	1	0
6	2	2	1	1	1	2	3	1	2	3	2	2	3	2	2	3	2	2	3	2	3	3	3	1	3	3	3	1	0	1	2	1	1	2	2	1
7	1	1	0	2	1	0	2	3	0	0	1	1	1	2	1	1	2	2	0	1	3	3	1	3	3	2	3	2	1	0	3	0	1	3	2	1

NUMBER OF CORRECT RESPONSES FOR EACH SUBJECT
PER TRIAL BY SIMILARITY/DISSIMILARITY AND ITEM LENGHT

SEQUENCE B 1/4 BITS/SEC.

	TRIALS																															
	SIMILAR																				DISSIMILAR													
	1			2			3			4			5			6			7			8			9			1			2		
SUBJECTS	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4
1	2	3	0	0	2	1	1	1	1	2	3	1	1	2	1	1	3	2	1	2	1	2	2	1	2	2	1	2	0	0	1	1	1
2	1	0	0	2	0	1	1	0	2	1	1	2	3	2	2	2	3	2	3	3	2	3	3	3	3	3	3	1	2	0	1	2	1
3	2	2	1	3	0	0	3	0	1	2	0	3	1	3	3	1	2	3	2	3	3	3	3	3	3	3	3	0	1	0	3	2	1
4	2	1	0	1	1	1	2	1	1	3	2	1	3	3	2	2	3	2	2	3	3	3	3	3	2	3	3	2	0	2	3	3	0
5	2	0	1	2	2	0	2	1	0	3	1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	0	2	2	0
6	2	1	1	2	1	1	2	0	0	3	1	0	1	1	1	1	1	2	3	2	2	3	1	1	2	3	1	2	2	1	2	2	1
7	2	2	0	2	1	0	3	1	1	1	3	2	2	3	1	3	3	0	3	3	2	3	3	2	3	3	3	2	1	1	0	2	3

NUMBER OF CORRECT RESPONSES FOR EACH SUBJECT
PER TRIAL BY SIMILARITY/DISSIMILARITY AND ITEM LENGHT

SEQUENCE C 1/4 BITS/SEC.

	TRIALS																																							
	SIMILAR																						DISSIMILAR																		
	1			2			3			4			5			6			7			8			9			1			2			3			4			5		
SUBJECTS	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4
1	1	0	1	3	2	1	2	1	1	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	1	0	2	2	1	3	3	0	2	3	0	3	3	0
2	1	1	0	3	1	0	2	1	2	3	2	2	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	0	2	2	3	2	2	3	2	3	2	3	3	3	3	3
3	1	2	3	3	2	1	3	2	2	3	3	2	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	0	1	1	2	1	1	2	1	3	2	1	3	3	3	3
4	0	2	2	1	2	1	2	2	1	0	2	1	3	3	1	1	3	2	2	3	3	3	3	2	2	3	3	2	0	2	2	1	1	3	0	1	3	3	2	1	2	3
5	2	0	2	3	1	1	1	2	2	3	3	3	2	3	3	2	3	3	3	3	3	3	3	3	3	3	3	2	2	0	3	1	1	3	1	2	3	2	2	3	1	1
6	1	1	1	3	2	0	3	3	1	3	2	1	3	2	1	2	2	2	2	2	1	3	3	2	3	3	2	1	1	0	3	1	1	3	1	0	2	2	1	3	1	0
7	1	1	2	2	1	1	3	2	2	3	2	2	3	2	3	3	3	2	3	3	2	3	3	2	3	3	2	3	1	1	1	2	2	2	1	1	2	2	2	3	3	1

Appendix D

BITS OF UNCERTAINTY PROCESSED FOR EACH SUBJECT PER BLOCK BY ITEM LENGHT

SEQUENCE A 1/2 BITS/SEC.

SUBJECTS	BLOCK 1			BLOCK 2			BLOCK 3			BLOCK 4		
	2	3	4	2	3	4	2	3	4	2	3	4
1	5.8788	9.3240	10.6998	5.8788	8.3064	10.3758	5.8788	2.4822	10.6998	5.5050	3.9024	10.3758
2	5.5050	9.3240	8.7516	4.8678	7.6794	11.1246	5.8788	4.8678	11.7516	5.8788	7.1292	8.8992
3	3.9024	8.3064	10.3758	3.9024	4.8678	10.9482	5.8788	5.8788	10.3758	5.8788	7.1292	9.0000
4	5.8788	9.3240	11.7516	3.9024	8.8992	10.3758	4.8678	9.3240	11.3268	5.8788	7.1292	11.5032
5	4.8678	8.8992	10.6998	2.4822	8.8992	11.7516	0.0000	8.8992	10.6998	0.0000	8.8992	7.6794
6	6.0000	9.3240	11.3268	5.8788	8.3064	9.5004	5.5050	8.3064	10.9482	4.8678	7.5078	11.7516
7	4.8678	9.0000	10.6998	6.0000	8.7516	11.7516	4.8678	8.7516	11.1246	5.5050	4.8678	10.9482

BITS OF UNCERTAINTY PROCESSED FOR EACH SUBJECT PER BLOCK BY ITEM LENGHT

SEQUENCE B 1/2 BITS/SEC.

SUBJECTS	BLOCK 1			BLOCK 2			BLOCK 3			BLOCK 4		
	2	3	4	2	3	4	2	3	4	2	3	4
1	5.5050	9.3240	11.5032	5.8788	8.7516	11.5032	4.8678	9.3240	11.7516	5.5050	9.3240	11.5032
2	5.8788	9.3240	11.3268	5.8788	8.7516	11.3268	4.8678	7.1292	10.6998	4.8678	8.7516	11.1246
3	5.8788	7.6794	8.5050	4.8678	7.6794	2.4822	6.0000	5.5050	3.9024	5.8788	4.8996	0.0000
4	3.9024	9.0000	11.1246	5.8788	7.9482	7.1292	5.5050	7.6794	6.2436	2.4822	5.5050	7.5078
5	5.8788	8.8992	11.1246	6.0000	8.7516	11.1246	4.8678	5.5050	7.5078	3.9024	7.5078	7.1292
6	5.5050	9.3240	8.3064	5.5050	8.3064	11.3268	5.8788	3.9024	11.7516	6.0000	3.9024	7.1292
7	5.8788	9.0000	10.3758	6.0000	8.7516	9.8964	3.9024	8.7516	11.1246	5.5050	9.0000	10.9482

BITS OF UNCERTAINTY PROCESSED FOR EACH SUBJECT PER BLOCK BY ITEM LENGHT

SEQUENCE C 1/2 BITS/SEC.

SUBJECTS	BLOCK 1			BLOCK 2			BLOCK 3			BLOCK 4		
	2	3	4	2	3	4	2	3	4	2	3	4
1	5.8788	7.6794	11.1246	5.5050	7.5078	11.5032	4.8678	7.5078	9.3036	5.5050	6.2436	8.3064
2	4.8678	8.7516	12.0000	6.0000	8.3064	10.3758	4.8678	7.5078	10.9482	4.8678	2.4822	9.3036
3	4.8678	7.9482	11.3268	5.8788	9.5004	7.6794	4.8678	7.6794	9.0000	5.5050	8.8992	11.3268
4	5.8788	9.0000	11.3268	5.8788	8.3064	8.7516	4.8678	7.6794	10.6998	5.5050	7.9482	11.3268
5	5.5050	8.7516	10.9482	2.4822	9.3240	11.7516	0.0000	8.7516	10.9482	0.0000	8.3064	9.0000
6	6.0000	3.9024	9.5004	2.4822	6.2436	7.9482	3.9024	3.9024	6.2436	2.4822	2.4822	2.4822
7	3.9024	8.3064	8.7516	2.4822	8.7516	9.6822	4.8678	8.7516	7.6794	5.5050	8.7516	7.6794

BITS OF UNCERTAINTY PROCESSED FOR EACH SUBJECT PER BLOCK BY ITEM LENGHT

SEQUENCE A 1/4 BITS/SEC.

SUBJECTS	BLOCK 1			BLOCK 2			BLOCK 3			BLOCK 4		
	2	3	4	2	3	4	2	3	4	2	3	4
1	6.0000	7.6794	10.3758	5.8788	4.8678	11.5032	3.9024	7.5078	11.1246	2.4822	2.4822	9.6822
2	4.8678	9.3240	11.7516	2.4822	7.5078	10.9482	2.4822	7.6794	8.5050	2.4822	2.4822	2.4822
3	5.5050	7.6794	11.5032	3.9024	8.7516.	11.7516	3.9024	9.3240	10.7544	3.9024	8.8992	8.3064
4	6.0000	9.3240	11.3268	3.9024	9.0000	9.7488	3.9024	9.3240	9.3240	4.8678	7.6794	9.3240
5	4.8678	8.8992	11.3268	3.9024	8.3064	11.3268	2.4822	0.0000	9.3240	2.4822	2.4822	8.5050
6	6.0000	9.5004	10.6998	3.9024	9.0000	9.6822	3.9024	8.3064	4.8678	0.0000	6.2436	6.2436
7	5.5050	9.3240	11.1246	5.5050	8.7516	10.6998	5.5050	8.3064	9.7488	4.8678	7.5078	4.8996

BITS OF UNCERTAINTY PROCESSED FOR EACH SUBJECT PER BLOCK BY ITEM LENGHT

SEQUENCE B 1/4 BITS/SEC.

SUBJECTS	BLOCK 1			BLOCK 2			BLOCK 3			BLOCK 4		
	2	3	4	2	3	4	2	3	4	2	3	4
1	5.5050	8.7516	11.7516	2.4822	9.0000	11.5032	5.5050	7.6794	8.7516	0.0000	7.5078	8.7516
2	5.8788	9.3240	10.6998	3.9024	9.3240	11.7516	0.0000	7.5078	7.5078	0.0000	4.8996	2.4822
3	5.5050	8.8992	10.9482	4.8678	6.2436	10.9482	3.9024	0.0000	8.5050	2.4822	3.9024	0.0000
4	5.5050	9.0000	10.9482	5.5050	9.3240	11.5032	5.8788	4.8678	6.2436	2.4822	2.4822	2.4822
5	5.8788	9.3240	11.7516	5.8788	9.3240	11.3268	3.9024	6.2436	9.6822	0.0000	3.9024	2.4822
6	5.8788	9.0000	11.3268	5.8788	8.7516	11.5032	6.0000	7.9482	10.9482	5.5050	8.3064	7.5078
7	5.8788	9.3240	9.7488	5.5050	4.8996	10.3758	3.9024	0.0000	10.3758	0.0000	0.0000	4.8996

BITS OF UNCERTAINTY PROCESSED FOR EACH SUBJECT PER BLOCK BY ITEM LENGHT

SEQUENCE C 1/4 BITS/SEC.

SUBJECTS	BLOCK 1			BLOCK 2			BLOCK 3			BLOCK 4		
	2	3	4	2	3	4	2	3	4	2	3	4
1	5.5050	8.8992	11.3268	2.4822	7.1292	10.9482	2.4822	7.1292	11.1246	2.4822	3.9024	10.3758
2	3.9024	9.3240	7.6794	3.9024	7.5078	4.8678	3.9024	7.5078	6.2436	0.0000	2.4822	4.8996
3	5.8788	9.0000	7.9482	5.5050	8.3064	10.6998	5.5050	7.5078	8.3064	2.4822	2.4822	2.4822
4	6.0000	8.7516	10.3758	3.9024	8.3064	3.9024	0.0000	2.4822	3.9024	0.0000	0.0000	0.0000
5	5.8788	7.9482	11.1246	3.9024	7.5078	3.9024	0.0000	0.0000	2.4822	0.0000	0.0000	0.0000
6	6.0000	9.3240	11.7516	3.9024	3.9024	11.3268	0.0000	0.0000	9.6822	0.0000	0.0000	0.0000
7	5.8788	9.3240	10.3758	3.9024	8.7516	9.3036	2.4822	6.2436	6.2436	0.0000	2.4822	8.5050

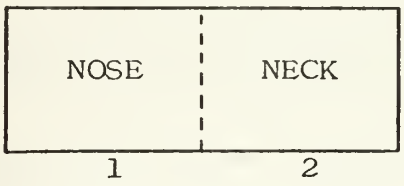
Appendix E

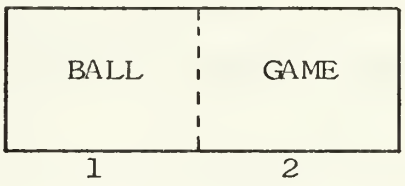
COMPUTER PROGRAM
FOR TRANSFORMATION OF DATA

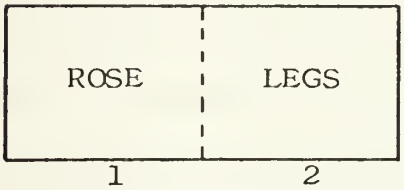
```
C
C       COMPUTER PROGRAM FOR TRANSFORMATION OF DATA
C
      REAL*4 MAT(2,21,4,3)
C
C       THIS PHASE OF THE PROGRAM READS AND PRINTS OUT THE
C       EXISTING DATA BASE
C
      DO 5 I=1,2
      DO 10 J=1,21
      READ(5,20) ((MAT(I,J,K,L),L=1,3),K=1,4)
   20 FORMAT(6F7.4)
      DO 15 K=1,4
      WRITE(6,25) (MAT(I,J,K,L,),L=1,3)
   25 FORMAT(3(F7.4,2X),/)
   15 CONTINUE
   10 CONTINUE
    5 CONTINUE
C
C       THIS PHASE TRANSFORMS THE DATA BASE
C
      DO 30 I1=1,2
      DO 35 J1=1,21
      DO 40 K1=1,4
      MAT(I1,J1,K1,1)=MAT(I1,J1,K1,1)*2
      MAT(I1,J1,K1,2)=MAT(I1,J1,K1,2)*1.2631
   40 CONTINUE
   35 CONTINUE
   30 CONTINUE
C
C       THIS PHASE PRINTS OR PUNCHES THE NEW TRANSFORMED
C       DATA BASE
C
      DO 45 I2=1,2
      DO 50 J2=1,21
      WRITE(6,60)((MAT(I2,J2,K2,L,),L2=1,3),K2=1,4)
   60 FORMAT(' ',6(F7.4),/,' ',6F7.4)
   50 CONTINUE
   45 CONTINUE
      STOP
      END
C
C       THIS PART OF THE PROGRAM CONTAINS THE DATA BASE TO
C       BE TRANSFORMED
C
```

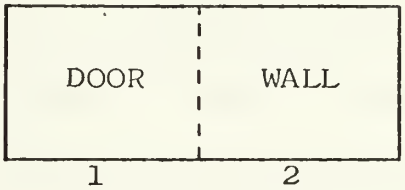
Appendix F

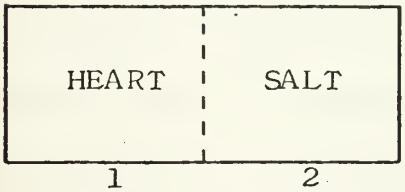
TWO - WORD
DISTRIBUTION ARRANGEMENTS

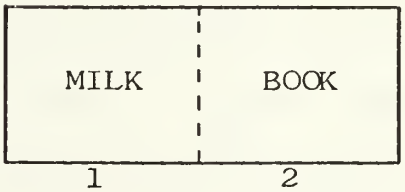








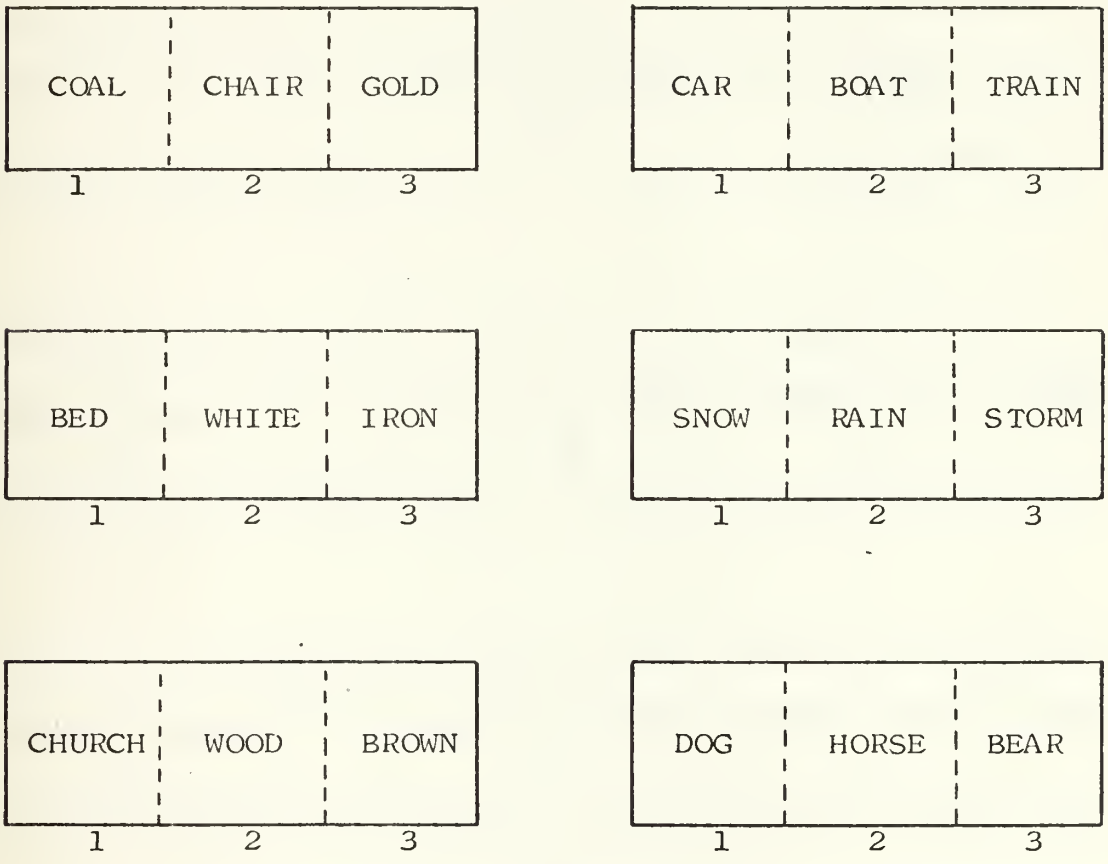




The words in the column numbered 1 were the ones designated as correct responses.

Appendix G

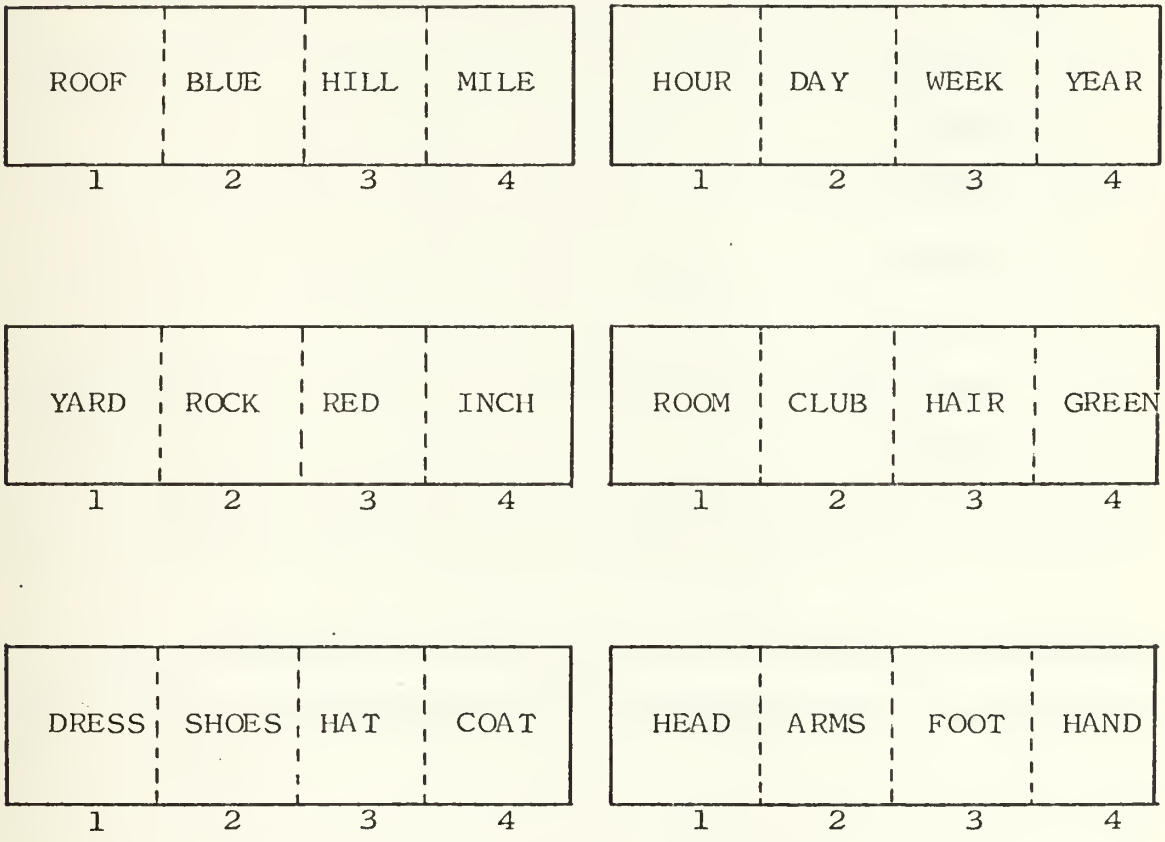
THREE-WORD
DISTRIBUTION ARRANGEMENTS



The words in the column numbered 1 were the ones designated as a correct response.

Appendix H

FOUR - WORD
DISTRIBUTION ARRANGEMENTS



The words in the column numbered 1 were the ones designated as correct responses.

Appendix I

UNCERTAINTY U_K FOR TWO-WORD ITEMS

PERMUTATION OF CHOICES		BITS OF INFORMATION $-6\sum_{i=1}^{n} P_i \text{ LOG } P_i$
6	6	6.0000
7	5	5.8788
8	4	5.5050
9	3	4.8678
10	2	3.9024
11	1	2.4822
12	0	0.0000

This represents the total amount of bits of information for the given arrangement in a particular block consisting of two trials.

Appendix J

UNCERTAINTY U_K FOR THREE-WORD ITEMS

PERMUTATION OF CHOICES	BITS OF INFORMATION	PERMUTATION OF CHOICES	BITS OF INFORMATION
4 4 4	9.5004	9 2 1	6.2436
5 4 3	9.3240	6 6 0	6.0000
6 3 3	9.0000	7 5 0	5.8788
5 5 2	8.8992	8 4 0	5.5050
6 4 2	8.7516	10 1 1	4.8996
7 3 2	8.3064	9 3 0	4.8678
6 5 1	7.9482	10 2 0	3.9024
7 4 1	7.6794	11 1 0	2.4822
8 2 2	7.5078	12 0 0	0.0000
8 3 1	7.1292		

Appendix K

UNCERTAINTY U_K FOR FOUR-WORD ITEMS

PERMUTATION OF CHOICES	BITS OF INFORMATION	PERMUTATION OF CHOICES	BITS OF INFORMATION
3 3 3 3	12.0000	6 4 2 0	8.7516
4 3 3 2	11.7516	8 2 1 1	8.5050
4 4 2 2	11.5032	7 3 2 0	8.3064
5 3 2 2	11.3268	6 5 1 0	7.9482
4 4 3 1	11.1246	7 4 1 0	7.6794
5 3 3 1	10.9482	8 2 2 0	7.5078
6 2 2 2	10.7544	9 1 1 1	7.2408
5 4 2 1	10.6998	8 3 1 0	7.1292
6 3 2 1	10.3758	9 1 2 0	6.2436
5 5 1 1	9.8964	6 6 0 0	6.0000
6 4 1 1	9.7488	7 5 0 0	5.8788
7 2 1 2	9.6822	8 4 0 0	5.5050
4 4 4 0	9.5004	10 1 1 0	4.8996
5 4 3 0	9.3240	9 3 0 0	4.8678
7 3 1 1	9.3036	10 2 0 0	3.9024
6 3 3 0	9.0000	11 1 0 0	2.4822
5 5 2 0	8.8992	12 0 0 0	0.0000

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...BSTRACT

The purpose of the experiment was to determine whether a constant information processing rate would occur when subjects in verbal discrimination (VD) learning were presented a mixture of items of different lengths. Forty-two Naval Postgraduate School students served in a VD experiment with a random mixture of 2-, 3-, and 4-word items at presentation rates of $\frac{1}{2}$ or $\frac{1}{4}$ bits of information per second. Half the items had similar and half, dissimilar words. The VD list had 6 each, of 2-, 3-, and 4-word items resulting in 6 bits of information for the 2-word items, 9.51 bits for the 3-word items, and 12 bits for the 4-word items for an overall presentation load of 27.51 bits of information. The information content of 2-, and 3-word items was normalized to agree with the 12-bit base of 4-word items for analysis. The similarity variable was disregarded, since it was not significant as a main effect. The results showed that, at each presentation rate, 2-, 3-, and 4-word items were learned at the same information processing rate. Moreover, the interaction between presentation rate and blocks of trials showed an expected multiplicative function such that the performance of one group could be predicted with 93.5 percent accuracy.

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